Marine geospatial information management

2024

United Nations

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FOREWORD

In the summary of *The Second World Ocean Assessment*, it is noted that:

> The ocean covers more than 70 per cent of the surface of the planet and forms 95 per cent of the biosphere. Changes in the ocean drive weather systems that influence both land and marine ecosystems. The ocean and its ecosystems also provide significant benefits to the global community, including climate regulation, coastal protection, food, employment, recreation and cultural well-being. Those benefits depend, to a great extent, on the maintenance of ocean processes, marine biological diversity and related ecosystem services.[1]

The United Nations Convention on the Law of the Sea was adopted in 1982 after almost a decade of negotiations and entered into force in 1994. It is often referred to as a "constitution for the oceans". By providing legal certainty, including through the establishment of clear maritime zones, rules for boundary delimitation and a comprehensive dispute settlement system, the Convention has done much to guarantee the peaceful uses of the ocean. Through its provisions on the conservation and management of living and non-living resources, the protection and preservation of the marine environment and the establishment of a regime for the exploration and exploitation of the deep seabed as the common heritage of humankind, it has promoted the equitable, sustainable and efficient utilization of the ocean. In addition, the Convention touches on various aspects of what is now encompassed in the 2030 Agenda for Sustainable Development and its Sustainable Development Goals.

Marine geospatial data and information play a critical role in the implementation of the Convention and support informed decision-making, aimed at the maintenance of ocean processes, marine biological diversity and related ecosystem services.

Marine geospatial data and information underpin the definition of all marine spaces and the regulation of a range of diverse activities carried out at sea and regulated pursuant to the Convention, including: traffic separation schemes

- Submarine pipelines
- Artificial islands, installations and structures
- Living resources, such as fish stocks, marine mammals and sedentary species
- Non-living resources, such as oil, gas and other mineral resources
- Reports on publicly relevant events that occur at sea
- Environmental impact assessments and activities related to the prevention, reduction and control of pollution of the marine environment
- Marine scientific research

Although notable progress has been made in the management of marine geospatial data and information over the past two decades, more work remains to be done to address considerable gaps related to various aspects of marine geospatial data and information globally. The gaps

1 A/75/232/Rev.1.

were identified in *The Second World Ocean Assessment*[2,3] which was an update to the first such assessment, *The First Global Integrated Marine Assessment*,[4] and was focused on the developments and changes known to have occurred since 2015.

Annex I to the present publication contains a summary of the marine geospatial and temporal data gaps that have been identified.

Recognizing the importance of marine geospatial information management, the General Assembly, in paragraph 388 of its resolution 77/248 of 30 December 2022, requested the Secretary-General to prepare a publication on marine geospatial information management.

The goal of the present publication is to promote a better understanding of the role that well-structured, integrated marine geospatial information management, including its infrastructure and systems, populated with reliable, timely and good-quality marine geospatial data, which are standardized, interoperable, integrated and available and accessible for cross-sectoral and multidisciplinary research, policy-development, decision-making and strategic actions, plays in improving the understanding of the challenges related to the sustainable future of the ocean and the planet, and in developing proper risk mitigation strategies.

I would like to express my thanks to Australia, Ecuador, Egypt, France, Greece, Italy, Nigeria, Singapore, Türkiye, the United States of America and the European Union for contributing to this publication, providing examples of marine geospatial data and information management projects (see annex II).

I would also like to express my gratitude to the following intergovernmental organizations that provided contributions (see annex III): the secretariats of the Convention for the Protection of the Marine Environment of the North-East Atlantic, Convention on Biological Diversity, Food and Agriculture Organization of the United Nations, Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization, International Hydrographic Organization, International Seabed Authority, Pacific Community and United Nations Development Programme.

2 *The Second World Ocean Assessment: World Ocean Assessment II* (United Nations publication, 2021).

3 Concerned by the declining state of the ocean, States Members of the United Nations, through the General Assembly, established the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects. The aim of the Regular Process is to provide an evaluation of the state of the global ocean, the services that it provides and the human activities that influence its state. The Regular Process is in its third cycle (2021–2025), with the first and second World Ocean Assessments published in 2016 and 2021, respectively. For more information, see www.un.org/regularprocess/.

4 Group of Experts of the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, *The First Global Integrated Marine Assessment: World Ocean Assessment I* (New York, United Nations, 2016).

João Miguel Ferreira de Serpa Soares
Under-Secretary-General for Legal Affairs and United Nations Legal Counsel
Office of Legal Affairs

ACKNOWLEDGEMENT

In January 2023, in a letter to States Members of the United Nations and intergovernmental organizations, the Office of Legal Affairs drew attention to paragraph 388 of General Assembly resolution 77/248 of 30 December 2022 on oceans and the law of the sea, requesting the Secretary-General to issue a publication on marine geospatial information management. Member States and intergovernmental organizations were invited to nominate experts to assist the Secretary-General in drafting the publication.

In response, Member States nominated the following experts:

Expert	*Nominating State*
María Dolores Alvarez (Vice-Chair)	Argentina
Mark Alcock (Chair)	Australia
Nsengiyunva Nadine	Burundi
Juan Pablo Benavides Monsalve	Chile
Andrea Baquerizo Torres	Ecuador
Julien Smeeckaert	France
Gabin Sogorb (alternate)	France
Boris Dorschel	Germany
Christina Pandermaraki	Greece
Dimitris Sakellariou (alternate)	Greece
Stellamaris Muthike (Vice-Chair)	Kenya
Hemanaden Runghen	Mauritius
Kamil Rybka	Poland
Nataly Kolchina (alternate)	Russian Federation
Alexey Shapoval	Russian Federation

The intergovernmental organizations nominated the following experts:

Expert	*Nominating intergovernmental organization*
Chee Hai Teo	Department of Economic and Social Affairs, United Nations
Emmanuel Blondel	Food and Agriculture Organization of the United Nations
Yong Baek	International Hydrographic Organization
Kioshi Mishiro	International Seabed Authority
Peter Pissierssens	Intergovernmental Oceanographic Commission, United Nations Educational, Scientific and Cultural Organization
Chris Moulton	OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic
Malakai Vakautawale	Pacific Community

The group of experts held 16 online meetings and one in-person meeting, which was held in New York from 13 to 17 November 2023. The following experts attended the in-person meeting:

Expert	*Nominating intergovernmental organization*
Mark Alcock (Chair)	Australia
Gabin Sogorb (alternate)	France
Boris Dorschel	Germany
Hemanaden Runghen	Mauritius
Kamil Rybka	Poland
Chee Hai Teo	Department of Economic and Social Affairs, United Nations
Emmanuel Blondel	Food and Agriculture Organization of the United Nations
Kioshi Mishiro	International Seabed Authority
Chris Moulton	OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic

In addition, the following staff members of the Division for Ocean Affairs and the Law of the Sea of the Office of Legal Affairs participated in the drafting of the publication: Robert Sandev, Senior Geospatial Information Officer and project coordinator; Luigi Santosuosso, Senior Legal Officer; Michael Shewchuk, Legal Officer; Shawn Stanley, Geospatial Information Officer; Emily Cikamatana, Geospatial Information Officer; Catherine Harwood, Legal Officer; Snježana Žaric, Geospatial Information Officer; Michael Moffat, Associate Legal Officer; Christine Nabwire, Library Assistant; Akanksha Pandey, Geospatial Information Assistant; Farah Ouirghimmie, intern; and Elizabeth Nwarueze, intern.

I. INTRODUCTION TO GEOSPATIAL INFORMATION MANAGEMENT

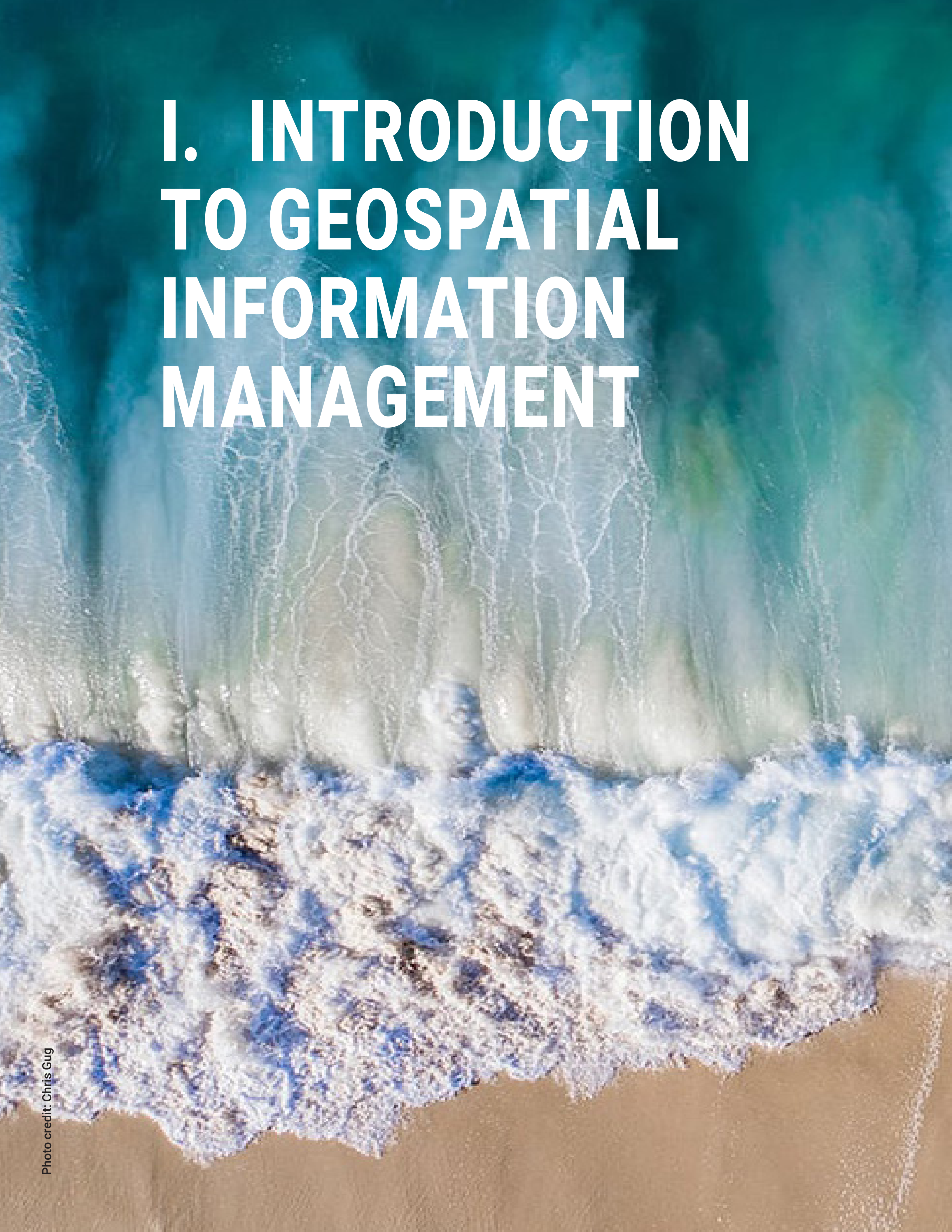


Photo credit: Chris Gug

A. What are marine geospatial data and information?

All human activities, environmental, biological and geological processes and the reality of ecosystems on Earth, including what is on, above and below the surface of the sea, land and the atmosphere above them, exist at a place and time. The term “geospatial information” describes the recording by humans of that information in order to understand the world and the consequences of human actions and to inform decisions on the sustainable use of its resources. Although it is possible to capture such information in many forms, the present publication is focused on marine geospatial data and information that can be used in electronic forms, in particular within geographic information systems.

Noting that there are various perspectives and definitions of geospatial data and information and following the practice of the United Nations Integrated Geospatial Information Framework, the terms “geospatial data” and “geospatial information” are used interchangeably in general contexts. In specific instances, “geospatial data” refers to observations or measurements; “geospatial information” refers to data that have been processed, organized, structured and presented.

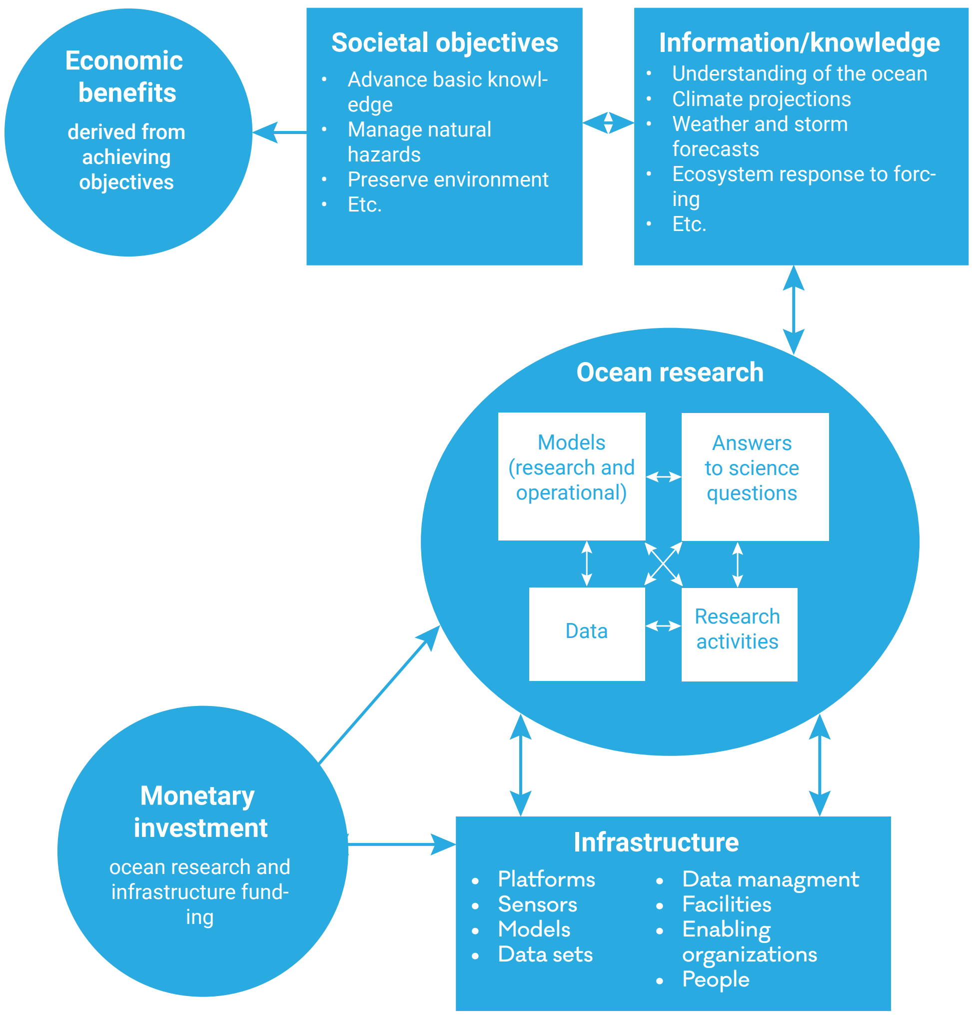
B. Why are marine geospatial data and information important?

Geospatial data and information are crucial for informed decision-making around the three pillars of sustainable development: society, the economy and the environment. Links among ocean infrastructure, scientific research and relevant societal objectives and their associated benefits are illustrated in figure I.

To be able to respond to current challenges, decision makers must have access to reliable, high-quality and timely geospatial information. Having that information benefits society, given that it enables the efficient allocation of resources and contributes to achieving the 2030 Agenda for Sustainable Development and its Sustainable Development Goals.

Figure I

Links among ocean infrastructure, scientific research and relevant societal objectives and their associated benefits



Source: National Research Council, *Critical Infrastructure for Ocean Research and Societal Needs in 2030* (Washington, D.C., National Academies Press, 2011).

C. What is marine geospatial data and information management?

The mass use of geospatial data and information in a digital format requires proper management to optimize their use and exchange. Geospatial data and information management encompasses the leadership, resources, structures, partnerships and practices required for the successful operation of geographic information systems within an entity, nationally, regionally or globally. Those elements are important to the expression of regulatory and planning processes. From the maritime perspective, leadership in geospatial information management drives a transformative approach that makes it possible to harmonize information collected from land and sea, inland waters and other water areas or surfaces.

Technological advances have been driven by the widespread use of marine geospatial data and information in recent years, promoting automation in the capture and management of information through geographic databases driving efficiencies in mapping, modelling and marine governance.

Strategic pathway 4 of the United Nations Integrated Geospatial Information Framework – with its four focus areas of data themes; custodianship, acquisition and management; data supply chains; and data curation and delivery – helps to establish guidelines and best practices for the collection and management of integrated geospatial information.[1] The objective is to encourage geospatial data custodians to comply with standards on the management, exchange and reuse of geospatial information, and encourage users to organize, plan, acquire, integrate, curate, publish and archive the data. Those good geospatial information management practices should be aligned with standards that facilitate data and technology interoperability, and thus provide integrated information for various geographic information systems.

D. Data principles in the context of marine geospatial data and information management

The principles that data are findable, accessible, interoperable and reusable – known as the FAIR guiding principles[2] were developed to improve the management and stewardship of scientific data and are generally applicable to marine geospatial data and information, and thus support the improved and rigorous management of that data and information. Adhering to those principles can be considered necessary for the proper

1 For more information on the strategic pathways, see https://ggim.un.org/UN-IGIF/part2.cshtml.

2 For more information, see Mark D. Wilkinson and others, "The FAIR guiding principles for scientific data management and stewardship", Scientific Data (March 2016). Available at https://doi.org/10.1038/sdata.2016.18.

management of marine geospatial data and information. Knowing that it is desirable but rare for data to be entirely findable, accessible, interoperable and reusable, a stepwise improvement starts with making data more findable. The increased findability of data will significantly improve marine geospatial data and information management.

Principles concerning collective data benefit, authority to control, responsibility to control and ethics – known as the CARE Principles for Indigenous Data Governance[3] – were drafted in response to the current movement towards open data and open science, which is not fully aligned with the rights and interests of indigenous peoples. Existing principles within the open data movement, such as the FAIR guiding principles, are primarily focused on the characteristics of data that will facilitate increased data-sharing among entities and do not give consideration to power differentials and historical contexts. The emphasis on greater data-sharing alone creates tensions for indigenous peoples who are asserting greater control over the application and use of indigenous data and knowledge for collective benefit.[4] For many indigenous communities, the oceans are central to their culture. Communities in and around the Pacific Ocean, in particular, are demanding greater consideration of their interests in decisions about the use of the oceans.

The CARE Principles are a framework that is relevant not only to indigenous peoples but, more broadly, to any initiatives that involve bringing data from the local to the global levels, which demands that consideration be given to the interests of the data creators, whether they are local communities or national entities in developing States. Setting aside the ethical aspects of the CARE Principles, such consideration should be treated as an overarching principle, given that data aggregation almost always requires an investment from the creator. Without considering mutual benefit, no system of global data access can be successful.

3 For more information, see the web page on the CARE Principles for Indigenous Data Governance, of the Global Indigenous Data Alliance. Available at www.gida-global.org/care.

4 For more information, see the flyer on CARE Principles for Indigenous Data Governance. Available at www.gida-global.org/s/CAREPrinciples_OnePagersFINAL_Oct_17_2019.pdf.

E. Importance of standards and standardization bodies

Standards help producers, custodians and users of geospatial data and information to use the same formats and best practices for the acquisition, stewardship, content interoperability and distribution of marine geospatial data. The success of a global geospatial data and information system relies on the implementation of standardized practices and formats.

There are many benefits to standardization. Some examples of organizations and their contributions to the implementation of the FAIR guiding principles are as follows:

(a) Findability: the International Organization for Standardization and its standard 19115, on geographic information metadata, which helps to improve the findability, or discoverability, of data;
(b) Accessibility: the Open Geospatial Consortium, for data exchange on the Internet, facilitates accessibility of data through the technologies that support online mapping applications;
(c) Interoperability: the World Meteorological Organization (WMO) and its standards for the collection and codification of weather observations support the compilation of global weather predictions in real time;
(d) Reusability: the Society of Exploration Geophysicists and its standards for data acquisition and encoding allow for the preservation and reuse of field and processed marine geophysical data.

The success of standardization depends on coordination bodies that create, implement and promote the standards. The bodies can be regional, national or international organizations, such as the International Organization for Standardization, they can be industry-based, such as the Open Geospatial Consortium, or they can be thematically based, such as the World Register of Marine Species.

Examples of bodies and initiatives that successfully develop and promote standards for marine geospatial data and information are:

(a) International Organization for Standardization, which has introduced standards ISO 19115, on geographic information metadata, and ISO 19152, on land administration domain model, in particular part 3 on marine georegulation, and its technical committee ISO/TC 211, on geographic information and geomatics;
(b) Food and Agriculture Organization of the United Nations (FAO), which coordinates standards for fisheries;

(c) International Hydrographic Organization, which has a principal aim to ensure that all the seas, oceans and navigable waters of the world are surveyed and charted, thereby supporting the safety of navigation and the protection of the marine environment, and its Maritime Limits and Boundaries Product Specification (S-121) (version 1.0.0), developed in response to General Assembly resolution 59/24.[5]

(d) WMO, the international standardization organization in the fields of meteorology, hydrology, climatology and related environmental disciplines;

(e) Intergovernmental Oceanographic Commission, through its International Oceanographic Data and Information Exchange programme, has been cooperating with WMO on an ocean data standards project, disseminating and promoting best practices and standards;

(f) Ocean Biodiversity Information System, a global open-access data and information clearing house for marine biodiversity for science, conservation and sustainable development;

(g) Darwin Core, a standard maintained by the Darwin Core Maintenance Interest Group, which includes a glossary of terms intended to facilitate the sharing of information about biological diversity by providing identifiers, labels and definitions and is primarily based on taxa and their occurrence in nature, as documented by observations, specimens, samples and related information;

(h) World Register of Marine Species, which provides an authoritative and comprehensive list of names of marine organisms, including information on synonymy, according the highest priority to valid names, although other names in use are included, in order that the register can serve as a guide for interpreting taxonomic literature led by taxonomic and thematic experts;

5 In paragraph 6 of the resolution, the Secretary-General was requested to improve the existing geographic information system for the deposit by States of charts and geographical coordinates concerning maritime zones, including lines of delimitation, in particular by implementing, in cooperation with relevant international organizations, the technical standards for the collection, storage and dissemination of the information deposited, in order to ensure compatibility among the geographic information system, electronic nautical charts and other systems developed by those organizations. Version 1 of the product specification was finalized for testing in December 2018. Subsequently, in paragraph 6 of its resolution 74/19, of 10 December 2019, the General Assembly noted the ongoing cooperation and progress achieved in the development by the International Hydrographic Organization, in cooperation with the Division for Ocean Affairs and the Law of the Sea, of the technical standards for the collection, storage and dissemination of the information deposited, which are not legally binding, in order to ensure compatibility among geographic information systems, electronic nautical charts and other systems, and re-emphasized the importance of the completion of those efforts through wide participation and reviews by Member States. Although no State is required to use S-121 in whole or in part, the submission of deposited material in a widely shared and recognized standardized format is highly desirable, in order to achieve the objective outlined in General Assembly resolution 59/24. Standard 19152, on land administration domain model, is the International Organization for Standardization counterpart to S-121 and reflects the knowledge obtained by the development of S-121, resulting in a generic model that allows for the extension of S-121 to be applied to all maritime limits and boundaries, including fisheries, marine protected areas, offshore renewables and petroleum. The development of those standards could support the electronic declaration and deposit of maritime limits and boundaries information and the seamless administration of land and sea through a combined land and marine land cadastre. Both standards are under testing.

(i) Open Geospatial Consortium, a group of experts committed to improving access to geospatial or location information and connecting people, communities and technology to solve global challenges and address everyday needs;

(j) Society of Exploration Geophysicists, a technical standards committee serving as a forum for the discussion of geophysical developments in relation to which standards for the acquisition and processing of geophysical data must be identified or improved;

(k) Infrastructure for Spatial Information in the European Community directive and its themes "sea regions" and "oceanographic geographical features".

II. GOING FROM LOCAL TO GLOBAL

Photo credit: Andrea Marandino

Marine geospatial data and information play a pivotal role in understanding and managing the oceans. As such, States have been collecting marine geospatial data and creating information to meet their national needs and address more specific, or localized, environmental, social and economic issues. The oceans, however, are interconnected, and to address regional and global challenges, a holistic view is required. Although it seems logical to use marine geospatial data and information at a broader level, the seamless sharing of marine geospatial data and information from a local to a global level poses significant challenges. The concept of "local to global" encompasses activities, phenomena or perspectives that occur at local, national, regional and global scales.

The fisheries sector is a good example of the wide range of activities that relate to marine geospatial data collection, management and end products. From national fisheries authorities to regional fisheries management organizations and global coordinating agencies, such as FAO, each level has its own role, data format requirements and specific products. The needs and challenges concerning data-sharing across the spectrum, from local to global, are explored in the present section.

A. Why is there a need to share marine geospatial data and information from the local to the global level?

To tackle regional and global issues, relevant marine geospatial data and information must be available. When coordination is missing at any level of data management, initiatives will serve only the originating level; local data serve local purposes only, and national data serve mainly national purposes. Access to local marine geospatial data and information is critical for national, regional and global decision-making, given that local data and information are usually more detailed, up-to-date and granular than data at any other level.

To use local marine geospatial data and information at the national, regional or global levels, additional data management work is usually needed at all levels to make the data usable. There are obvious benefits in doing that work, including:

(a) Data are available, duplication is prevented and the cost of data collection can be avoided;
(b) Data have multiple uses;
(c) Data collection at the local level is carried out by those with significant local knowledge and is usually of higher granularity;
(d) Data spatial and temporal scope are expanded.

The data flow can be reversed, and data gathered at a higher level can serve national and local purposes.

B. Challenges of going from local to global

Most of the challenges of going from the local level to the global level can be vastly reduced by partnerships and cooperation on data-sharing (starting at the national level) and by using internationally recognized standards. The list below builds on the report of the Working Group on Marine Geospatial Information of the United NationsCommittee of Experts on Global Geospatial Information Management [6] to summarize the primary challenges to sharing, using and reusing marine geospatial data and information across and between levels, from local to global.

6 Working Group on Marine Geospatial Information, United Nations Committee of Experts on Global Geospatial Information Management, "White paper on readily available and accessible (open) marine geospatial information" (New York, 2020). Available at https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/E-C.20-2020-31-Add_2-White-paper-on-readily-available-and-accessible-marine-geospatial-information-23Jul.pdf.

1. KNOWLEDGE OF THE STATUS OF DATA AND INFORMATION

To foster effective collaboration and enhance decision-making among diverse groups of stakeholders across different levels, the status of data and information must be known. Unlocking the wealth of existing marine geospatial data and information at the local, national, regional and global levels relies on two critical components: awareness of and access to available marine geospatial data and information.

With such constraints as mandates, funding and technical expertise, many organizations do not prioritize making known the existence of available geospatial data and information. To complicate matters, with multiple agencies and non-governmental organizations collecting, managing and curating marine geospatial data and information, it is sometimes unclear which entity to contact to access data. The risks of duplication of effort, economic loss, missed economic opportunities and ineffective policy decisions highlight the need for coordination and awareness across all levels. In some circumstances, a legal framework on geospatial data and information management could be a solution. The Infrastructure for Spatial Information in the European Community Directive is an example of such a legal framework established by the European Union.

Accessing data presents distinct challenges across various levels. Regional and global entities typically present marine geospatial data and information online. Sharing such data and information, however, can be challenging for some local or national agencies that have little or no Internet access. Solving the issue will require significant investment to expand information technology infrastructure.

Acquiring marine geospatial data and sharing the data and information come at a cost. To offset the cost, access to marine geospatial data and information can be subject to a fee.

Sharing marine geospatial data and information, in particular with external stakeholders, requires mutual trust among all parties involved. Concerns around such issues as national security, data misuse, intellectual property and economic, cultural and environmental sensitivities can be a barrier to data-sharing and information-sharing initiatives. Chapter IV of the present publication includes a more in-depth analysis of restrictions on access to data and information.

Photo credit: Taryn Schulz

2. IMPLEMENTATION OF STANDARDIZATION

A standard is a documented agreement between providers and consumers, established by consensus, that provides rules, guidelines or characteristics for ensuring that materials, products and services are fit for purpose. Standards related to marine geospatial data and information usually cover the characteristics of the data or information described but can include data quality and the methods for creating, managing and exchanging data or the descriptions of equipment used to undertake those tasks. Examples of standards bodies are listed in chapter I, section E. Marine geospatial information management standards could address:

(a) Data semantics (e.g. taxonomy);
(b) Language differences;
(c) Data formats;
(d) Quality issues;
(e) Coordination of reference systems and vertical datum differences;
(f) Accuracy of data requirements;
(g) Access to data, including ways of sharing geospatial data, such as metadata standards;
(h) Chains of reporting and reporting obligations for different bodies.

A further discussion of this topic can be found in the study entitled “A guide to the role of standards in geospatial information management”.[7]

7 Open Geospatial Consortium, International Organization for Standardization Technical Committee 211 Geographic Information and Geomatics and International Hydrographic Organization, “A Guide to the Role of Standards in Geospatial Information Management” (n.p., 2015). Available at https://ggim.un.org/documents/Standards%20Guide%20for%20UNGGIM%20-%20Final.pdf.

Photo credit: Alvaro Herrero

3. TECHNOLOGY

The task of collecting and managing marine geospatial data and information and the resources needed to do so are inherently connected with technology. The technological challenge is complicated by the fact that technology is constantly evolving. There is an obvious disparity in access to up-to-date equipment and software, owing to varying levels of funding.

The challenges of technological evolution and change are cross-cutting. All stakeholders are affected by growing volumes of data and the need to keep infrastructure and software up-to-date as a result of technological evolution. New or modernized information technology infrastructure and new procedures to archive securely large volumes of data can be used, but continuous investment in infrastructure, capabilities and standards are required.

Predicted future trends in geospatial information management are described in *Future Trends in Geospatial Information Management: the Five to Ten Year Vision* of the United Nations Committee of Experts on Global Geospatial Information Management.[8]

Strategic pathway 5[9] of the United Nations Integrated Geospatial Information Framework is focused on innovation and its potential, cost-effective technologies and process improvements, as well as opportunities to leapfrog.

8 Christin Walter, Ordnance Survey of Great Britain, *Future Trends in Geospatial Information Management: the Five to Ten Year Vision*, 3rd ed. (New York, United Nations Committee of Experts on Global Geospatial Information Management, 2020). Available at https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/Future_Trends_Report_THIRD_EDITION_digital_accessible.pdf.

9 See https://ggim.un.org/UN-IGIF/documents/SP5%20-%20Innovation%204Jul2020%20GLOBAL%20CONSULTATION.pdf.

4. CAPACITY DEVELOPMENT

Capacity development empowers individuals and entities with the right skill sets to:

(a) Recognize the relevance and potential applications of marine geospatial data and information;
(b) Collect, manage, process and share necessary marine geospatial data and information;
(c) Ensure compliance with directives, legislation and guidelines;
(d) Liaise with stakeholders.

Strategic pathway 8[10] of the United Nations Integrated Geospatial Information Framework concerns the need for capacity development and education programmes for all levels of government, organizations and communities. Continuous updates on the latest advances in marine geospatial technology, information technology solutions and data-collection methods would ensure an efficient use and reuse of data and information and help the stakeholders involved to adapt to the needs of one another across different levels.

In its "White paper on readily available and accessible (open) marine geospatial information",[8] the Working Group on Marine Geospatial Information of the United Nations Committee of Experts on Global Geospatial Information Management, called for the following:

(a) Development of data-sharing partnerships to facilitate the timely sharing of data among States, government agencies, the research and academic community, private data providers and other users and stakeholders;

10 See https://ggim.un.org/UN-IGIF/documents/SP8-Capacity_and_Education_19May2020_GLOBAL_CONSULTATION.pdf.

11 Working Group on Marine Geospatial Information, "White paper". Available at https://ggim.un.org/meetings/GGIM-committee/10th-Session/documents/E-C.20-2020-31-Add_2-White-paper-on-readily-available-and-accessible-marine-geospatial-information-23Jul.pdf.

(b) Implementation of internationally agreed standards, such as those of the International Organization for Standardization, the International Hydrographic Organization and the Open Geospatial Consortium, including standards for metadata, to make data-sharing easier and more discoverable;

(c) Collection and management of marine geospatial data with multi-use purposes in mind, and greater stakeholder awareness of the types and locations of information that are available;

(d) Participation in capacity-development opportunities when resources allow, and the active transfer of knowledge, tools and techniques that facilitate the collection, management and sharing of marine geospatial data in developing counterparts.

Photo credit: Patrick Webster

III. ROLE OF INTERGOVERNMENTAL ORGANIZATIONS IN MARINE GEOSPATIAL INFORMATION MANAGEMENT

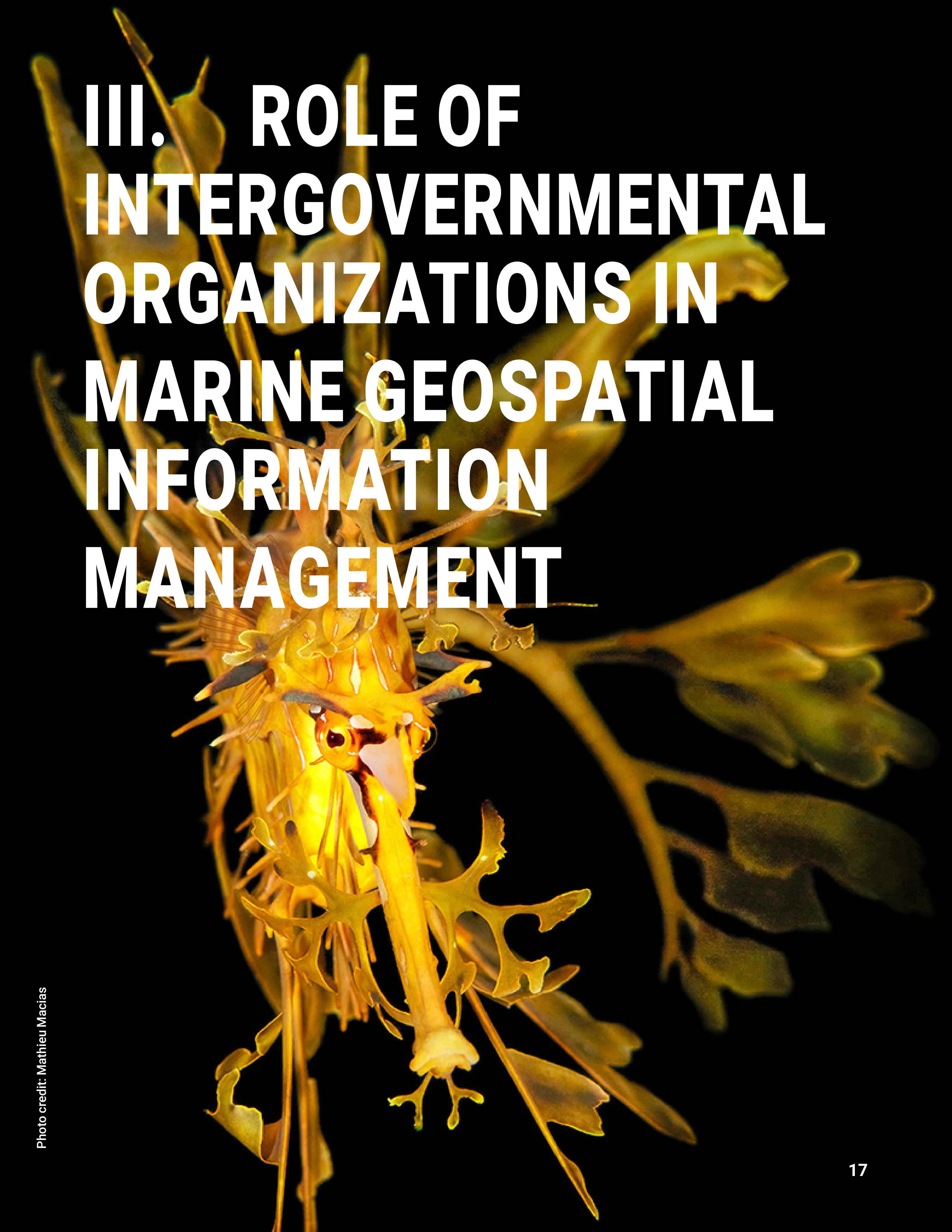


Photo credit: Mathieu Macias

Photo credit: Romeo Bodolai

A. Collective objectives and supporting actions and activities

Intergovernmental organizations provide a forum in which States coordinate and work collaboratively towards the achievement of common goals. By nature, their role is varied, covering an enormous range of objectives (as demonstrated by the breadth of information presented in annex III). Coordinating efforts, in particular in the marine environment, is critical, given that marine environments span geopolitical boundaries and that transboundary cooperation is the only way to ensure that the Sustainable Development Goals and their targets are reached.

The Goals are a major focus of action and activity for intergovernmental organizations. Such organizations that are concerned with the marine environment refer to Goal 14, on life below water, and its associated targets and indicators, the overall aim of which is to conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Goal 14, target 14.c, is aimed at enhancing the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of General Assembly resolution 66/288, entitled “The future we want”, of 27 July 2012. That legal framework needs reliable and robust marine geospatial data and information to enable the enhancement of conservation and sustainable use.

The United Nations Decade of Ocean Science for Sustainable Development (2021–2030)[12] is an initiative to stimulate ocean science and knowledge generation in order to reverse the decline of the state of the ocean system and create new opportunities for the sustainable development of the massive marine ecosystem. It promotes the attainment of the targets of Goal 14 by raising awareness and recognizing efforts to achieve the Goal overall.

Intergovernmental organizations coordinate the establishment of standards and their implementation, for example to ensure effective and sustainable data exchange in a timely fashion, which can lead to increased demand for the submission of scientific data and information in a digital, georeferenced format that is compatible with multiple organizations. Intergovernmental organizations will respond to that demand by:

(a) Facilitating common approaches (harmonization);
(b) Promoting standardization, encompassing the inception of new standards, encouraging the development of data descriptions (metadata), fostering data-sharing opportunities and providing implementation guidelines;
(c) Supporting capacity-building;
(d) Providing tools in support of cross-domain and ecosystem approaches to geospatial data and information management.

Such mechanisms help intergovernmental organizations to collate data effectively, from the local to the regional levels, facilitate data exchange, foster collaboration and coordination to address environmental challenges and identify possible knowledge gaps, supporting a multidisciplinary approach for the implementation of effective solutions to achieve transboundary objectives.

In addition, marine geospatial data and information can be provided without any restrictions. More use could be made of the digital public goods initiative,[13] to which the Secretary-General referred in the road map for digital cooperation,[14] his report on the implementation of the recommendations of the High-level Panel on Digital Cooperation.[15] Intergovernmental organizations can help to contribute to sharing without barriers by providing content and encouraging its provision using open data principles. In some circumstances, however, access management will be required, in particular when the organizations are responsible for sensitive data and information (see chapter IV), and in those cases open data access may not be appropriate.

12 See https://oceandecade.org/.

13 See www.un.org/techenvoy/content/digital-public-goods.

14 See www.un.org/en/content/digital-cooperation-roadmap/.

15 A/74/821 para. 78.

Infrastructure for Spatial Information in the European Community and other directives, such as the European Union marine strategy framework directive,[16] provide legal frameworks to encourage the sharing of environmental spatial information among organizations and facilitate better policymaking across boundaries and data domains by promoting the role of intergovernmental organizations in executing those critical functions. For example, the thirteenth preambular paragraph of the marine strategy framework directive provides that: "Where practical and appropriate, existing institutional structures established in marine regions or subregions, in particular Regional Sea Conventions, should be used to ensure such coordination".

B. Facilitating common approaches

Agreement on common scientific approaches and methodologies forms the foundation of any collective effort. To advance the implementation, development and achievement of agreed objectives, consensus must be reached on technical details, including standards.

Intergovernmental organizations provide the foundation for ensuring that geospatial data and information can be gathered and prepared across the entire area of interest. Standardized approaches should form the basis of efforts, within the mandate of the organizations. The agreed approaches should be made available with a view to promoting transparency and fostering broader adoption. Furthermore, mechanisms should be established for the continuous monitoring and evaluation of the implementation of the agreed approaches to ensure their effectiveness. The harmonization of approaches and methodologies requires a collaborative and inclusive process that reflects the diverse needs and perspectives of all stakeholders involved.

Examples of such harmonization and related actions in practice include:

(a) FAO fisheries management regional data-collection reference frameworks, such as that of the Western Central Atlantic Fishery Commission;[17]

(b) Collective contribution of the International Hydrographic Organization and the Intergovernmental Oceanographic Commission of high-resolution mapping of the international seabed area, including for the General Bathymetric Chart of the Oceans;[18]

(c) Standard reporting and metadata templates of the International Seabed Authority to guide contractors in reporting on deep-sea exploration, including mid-waters, in line with regulations;[19]

16 European Parliament and Council of the European Union, directive 2008/56/EC. Available at https://research-and-innovation.ec.europa.eu/research-area/environment/oceans-and-seas/eu-marine-strategy-framework-directive_en.

17 See www.fao.org/wecafc/data/dcrf.

18 See www.gebco.net/about_us/seabed2030_project/.

19 See www.isa.org.jm/exploration-contracts/reporting-templates/.

Photo credit: Edwar Herreno Para

(d) Coordinated Environment Monitoring Programme of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Agreement 2016-01).[20]

C. Promoting standardization

Leveraging the important role of intergovernmental organizations in promoting the inception, adoption and implementation of standards to their members and partners results in overall "standardization". In marine geospatial data and information management, standardization is driven by several main sources: the International Organization for Standardization, the Open Geospatial Consortium and the International Hydrographic Organization. The International Organization for Standardization and the Open Geospatial Consortium provide the backbone of geographic information standards and are widely used in the United Nations system, by intergovernmental organizations in general and across marine domains. In marine fisheries,

20 See www.ospar.org/documents?v=32943.

standards of those two organizations have been recommended for use by the Coordinating Working Party on Fishery Statistics.[21]

1. BUILDING NEW STANDARDS

Standardization is an important tool in the exchange of geospatial data. Building upon the harmonization of methodologies, intergovernmental organizations have a role in coordinating the response to gaps in standards by augmenting existing or creating new standards and promoting their implementation. Standards can include technical specifications for marine geospatial data and products.

Technical specifications have been produced by intergovernmental organizations to address the standardization of marine geospatial information and its exchange, examples of which include, a standard for maritime limits and boundaries of the International Hydrographic Organization (S-121), the United Nations Fisheries Language for Universal Exchange[22] and specifications for the exchange of fisheries geospatial data produced by the Coordinating Working Party on Fishery Statistics.[23]

The publication of available standard reference marine geospatial information products will be central to achieving global objectives, such as the Sustainable Development Goals, and the coordinating role of intergovernmental organizations in that process is crucial in establishing close partnerships and collaborative arrangements with institutions at the national, regional and global levels.

Examples of the successful development by intergovernmental organizations of global geospatial information standardized products, include:

(a) On physical features, the General Bathymetric Chart of the Oceans, operating under the auspices of the International Hydrographic Organization and the Intergovernmental Oceanographic Commission of UNESCO, and the Atlas of Geomorphic Features, of GRID-Arendal and the United Nations Environment Programme (UNEP);

(b) On marine protected areas, the Protected Planet data set[24] of the UNEP World Conservation Monitoring Centre and the International Union for Conservation of Nature;

(c) On other effective area-based conservation measures, the Vulnerable Marine Ecosystems database[25] of FAO, a global inventory of fisheries measures to protect vulnerable marine ecosystems.

21 For more information, see FAO, "Recommended GIS standards". Available at www.fao.org/cwp-on-fishery-statistics/sharing-practices/gis-recommended-standards.

22 See https://unece.org/trade/uncefact/unflux.

23 See www.fao.org/3/cc6734en/cc6734en.pdf.

24 See www.unep-wcmc.org/en/protected-planet.

25 See www.fao.org/in-action/vulnerable-marine-ecosystems/vme-database/en/vme.html.

Building global data sets often implies a custodian role for intergovernmental organizations in pulling data and information from either national or regional sources. Depending on the nature of the data, and their evolution across time, data collation may become challenging and eventually compromise the long-term sustainability of the data sets. Intergovernmental organizations that are custodians of the information must, therefore, play an important coordinating role to ensure that global data sets are maintained into the future.

Some global geospatial marine information products are likely to be crucial for the achievement of the Sustainable Development Goals but are unavailable within the United Nations system or from intergovernmental organizations. For example, there is an absence of a comprehensive global geospatial database on maritime jurisdictions, established to be consistent with the United Nations Convention on the Law of the Sea, including the high seas and the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction.

Among intergovernmental organizations, there is a growing need to use marine geospatial data and information at the global level for the purposes of achieving the Sustainable Development Goals, including, for example, the identification of marine fisheries and stocks for Goal 14. Recently, there has been discussion within FAO through the Fisheries and Resources Monitoring System and the Coordinating Working Party on Fisheries Statistics of the ways to address such needs and to connect to existing standardization initiatives on water jurisdiction areas.

In the long term, the standard for maritime limits and boundaries of the International Hydrographic Organization (S-121) is aimed at addressing those needs by providing specifications for the electronic deposit and exchange of maritime limits and boundaries defined under the United Nations Convention on the Law of the Sea. In the short term, however, intergovernmental organizations and all marine geospatial data and information users must find alternative solutions to manage geospatial domain information without necessarily referring to the Convention.

Digital data on maritime jurisdictions are often needed by fisheries experts to identify and characterize the geographic coverage of stocks and fisheries in the FAO Global Record of Stocks and Fisheries.[26] Separately, a global inventory of reference fishery areas is being developed to support the identification of fisheries. The standard for maritime limits and boundaries of the International Hydrographic Organization is extendable and, therefore, provides an opportunity to draw a path for further standardization of digital information on marine fishing zones. Intergovernmental organizations could play a growing role in marine geospatial information standardization through active

26 See https://i-marine.d4science.org/web/grsf/data-catalogue.

Photo credit: Michael Sswat

and joint participation in international standardization bodies and technical committees, such as technical committee ISO/TC 211 of the International Organization for Standardization and the Open Geospatial Consortium, to prepare the next generation of geographic information standards, in response to community needs. Building profiles, for example for fisheries, under ISO 19115, is one area of work in which intergovernmental organizations may involve themselves.

Intergovernmental organizations must approach standardization in a cross-domain way. Marine geospatial information may be combined with other domains, such as statistical or taxonomic information. For example, the standardization of georeferenced multidimensional catch and effort time series in marine fisheries should take into account geospatial, statistical, taxonomic, fisheries and other domain standards. Standardization of the geospatial information should then be carried out in an open manner to connect with other domains for which different standards apply.

2. ENCOURAGING DATA DESCRIPTION (METADATA)

Data set descriptions, known as metadata, are gathered alongside data to aid discovery and to ensure that the usefulness of the data is maximized. Metadata are critical supplementary information describing the data. The principal geographic information metadata standard is standard 19115 of the International Organization for Standardization, which provides schemas to describe geospatial data sets, including their content, identification, distribution, spatial and temporal data coverage, quality and provenance. Best practice requires that metadata be recorded in parallel with the data management steps, from data collection through to dissemination.

Standardized metadata resources can be read by computer systems, which means that the data comply with the FAIR guiding principles.

Although metadata are crucial in describing data, the complexity of geographic information standards makes metadata production difficult for those who are not experts and constitutes a barrier to describing data. Intergovernmental organizations can play a role in introducing simplified information models, with a view to creating minimum requirements that can guarantee that data are described sufficiently. The provision of data with associated metadata with required content allows experts and others to understand the information and ensure the long-term usefulness of the data for the promotion of marine scientific research. The Dublin Core Metadata Element Set[27] is an example of a reference backbone that can be used to implement templates on the basis of such models.

Metadata supports the FAIR guiding principles by providing controlled vocabularies, known as data dictionaries or registers. Intergovernmental organizations have a key role in building a consensus to establish controlled vocabularies. An example of that process is the Fisheries Data Interoperability ad hoc working group[28] initiative, promoted through the Coordinating Working Party on Fishery Statistics and led by the Fisheries and Aquaculture Resources Use and Conservation Division of FAO. In that initiative, reference fisheries digital data sets are developed by multiple intergovernmental organizations, such as regional fisheries management organizations, working together to develop

27 See www.dublincore.org/specifications/dublin-core/dces/.

28 See https://github.com/fdiwg.

geospatial-enabled regional and global fisheries databases, such as the Fisheries and Resources Monitoring System Global Tuna Atlas.29

3. FOSTERING DATA EXCHANGE AND DISSEMINATION

Intergovernmental organizations develop standards for data exchange by establishing content and presentation. Managing the presentation of information is especially important for informing non-expert audiences and facilitating consistent decision-making. Effective presentation bridges the gaps between scientific experts, scientific disciplines, decision makers and the public. An initiative that illustrates this process is the FAO Database on Vulnerable Marine Ecosystems,[30] which is based on the geographic and temporal extent of deep-sea fisheries management measures taken by regional fisheries management organizations.

The release and exchange of geospatial marine data and information can be sensitive issues. Intergovernmental organizations play an important role in improving access by negotiating with data owners. The report of the Secretary-General on the road map for digital cooperation provides a pathway for intergovernmental organizations to improve access to high-quality data and information products.[31] Success stories in that regard are presented in annex III to the present publication and include but are not limited to the Global Ocean Observing System,[32] the Array for Real-time Geostrophic Oceanography,[33] launched by the Intergovernmental Oceanographic Consortium and WMO, the International Oceanographic Data and Information Exchange, the close cooperation between the Committee of Experts on Global Geospatial Information Management and the marine spatial data infrastructures working group of the International Hydrographic Organization, and the maritime limits portal of France.[34]

Once data have been collected and assessed and have produced reliable information outputs, with clearly defined data-sharing paths, the data and information can be reused for multiple purposes. Data reuse fosters capacity-building and increases the financial and scientific value of the data, making it possible for others, such as regional organizations, to access and build upon the original work.

Agreeing upon objectives, collecting and assessing data and reaching consensual conclusions on the assessed outcomes require a significant amount of collective work

29 See www.fao.org/3/cc4342en/cc4342en.pdf.

30 See www.fao.org/in-action/vulnerable-marine-ecosystems/vme-database/en/vme.html.

31 A/74/821.

32 See www.goosocean.org/.

33 See https://argo.ucsd.edu/.

34 See https://maritimelimits.gouv.fr/.

and investment, but the rewards that follow extend beyond the level of intergovernmental organizations to include the global community.

4. SUPPORTING CAPACITY-BUILDING

Intergovernmental organizations play a critical role in capacity-building programmes and projects through their support for the deployment of marine geospatial information management standardization. The provision of implementation guidelines alongside digital public goods is aimed at facilitating efficient and sustainable capacity-building. Fostering such sustainable capacity-building can encourage the support of national data managers for the development of national marine geospatial data strategies and management plans.

An example of support from an intergovernmental organization for capacity-building is the International Seabed Authority hosting experts from African States selected as part of the Africa Deep Seabed Resources[35] project within the secretariat of the Authority. The project is implemented by the Authority in partnership with the African Union and the Norwegian Agency for Development Cooperation following a joint voluntary commitment registered at the 2017 United Nations Ocean Conference by the Authority and the African Mineral Development Centre of the Economic Commission for Africa (since transferred to the African Union) in support of the sustainable development of Africa's Blue Economy. Secondments build on existing capacity-building initiatives to provide national experts with technical skills on matters related to the deep seabed and help the secretariat of the Authority to benefit from the contribution of those experts to advance specific tasks identified in partnership with the Legal and Technical Commission of the Authority.

The Intergovernmental Oceanographic Commission of UNESCO is another example of support and is aimed at increasing the institutional and professional capacity of States to manage marine research and observation data and information as part of the Ocean Teacher Global Academy[36] of the Commission.

5. COORDINATING A CROSS-DOMAIN OR KNOWLEDGE ECOSYSTEM APPROACH

Standardization enables intergovernmental organizations to coordinate across domains and establish a knowledge ecosystem approach, examples of which include:

35 See www.isa.org.jm/capacity-development-training-and-technical-assistance/adsr-experts/.

36 See https://classroom.oceanteacher.org/.

(a) Data catalogues, such as the Ocean Biodiversity Information System,[37] to which intergovernmental organizations, including the International Seabed Authority, contribute, and the Fisheries GeoNetwork Platform[38] of FAO;

(b) Tools for exploring data through specific geospatial data portals, facilitating the discovery and reuse of, and access to, data, such as the GeoInfo[39] map viewer of the Fisheries and Aquaculture Resources Use and Conservation Division of FAO, the OSPAR Data & Information Management System[40] of the OSPAR Commission, the Map and data service of the Baltic Marine Environment Protection Commission[41] and the protected areas impact maps of FAO and UNEP;

(c) Information hubs, which are aimed at presenting generalized marine information, including geospatial information, such as the Ocean InfoHub Project[42] established by the International Oceanographic Data and Information Exchange of UNESCO.

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37 See https://obis.org/2021/06/10/isa.

38 See www.fao.org/fishery/geonetwork/.

39 See www.fao.org/fishery/geoserver/geoinfo/.

40 See https://odims.ospar.org/.

41 See https://helcom.fi/baltic-sea-trends/data-maps/.

42 See https://oceaninfohub.org/.

IV. MANAGING RESTRICTIONS TO DATA ACCESS

Photo credit: Tom St George

A. Restrictions on access to marine geospatial information and related consequences

Access to information enables its reuse, providing far-reaching benefits for the wider community and often benefiting areas of work beyond those for which the data were initially collected. Although open access to marine geospatial data and information provides the greatest economic and reuse potential, there are legitimate reasons for data to be placed under restricted access. In those cases, the sensitivities of the data owners must be respected, but access under the least restrictive terms should be encouraged. Areas under which legitimate barriers to access may remain are described below.

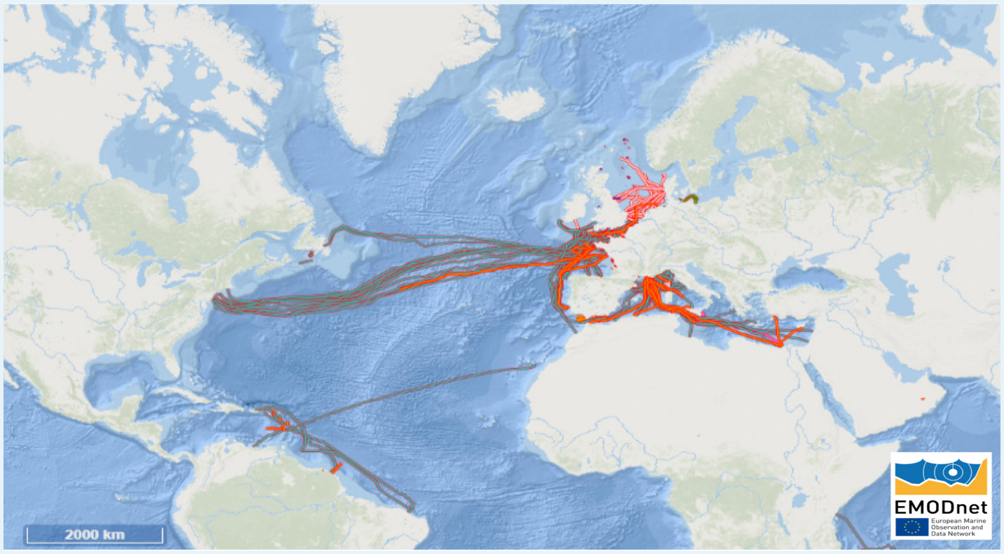
1. SECURITY

The release of detailed information on matters that are considered by a State to be sensitive for reasons of national security will likely have some access constraints. Sensitive data and information could include information related to military facilities and activities and critical infrastructure, such as submarine cables and pipelines. Bathymetry and detailed hydrographic soundings are considered to be sensitive by many States.

For critical infrastructure, such as submarine cables, there will often be a need to find a balance between keeping its location confidential and protecting it from unintentional damage by those who have a legitimate interest in working near it. An example of where this issue has been addressed is the legal obligation under the United Nations Convention on the Law of the Sea, which governs future exploitation of seabed minerals in the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction, and which provides an obligation to protect submarine cables on the seafloor. For the regulator and miners to be adequately protected and to prevent any unintended interference with the infrastructure, the cable operators must share information about the position of submarine cables with the regulator. The onus to exchange information has been enshrined in a memorandum of understanding between the International Cable Protection Committee and the International Seabed Authority.[43] An example of a map showing the approximate positions of telecommunications cables is provided in figure II.

43 See www.isa.org.jm/wp-content/uploads/2022/04/MOU-ICPC.pdf.

Figure II
Map of telecommunications cables limited to approximate positions



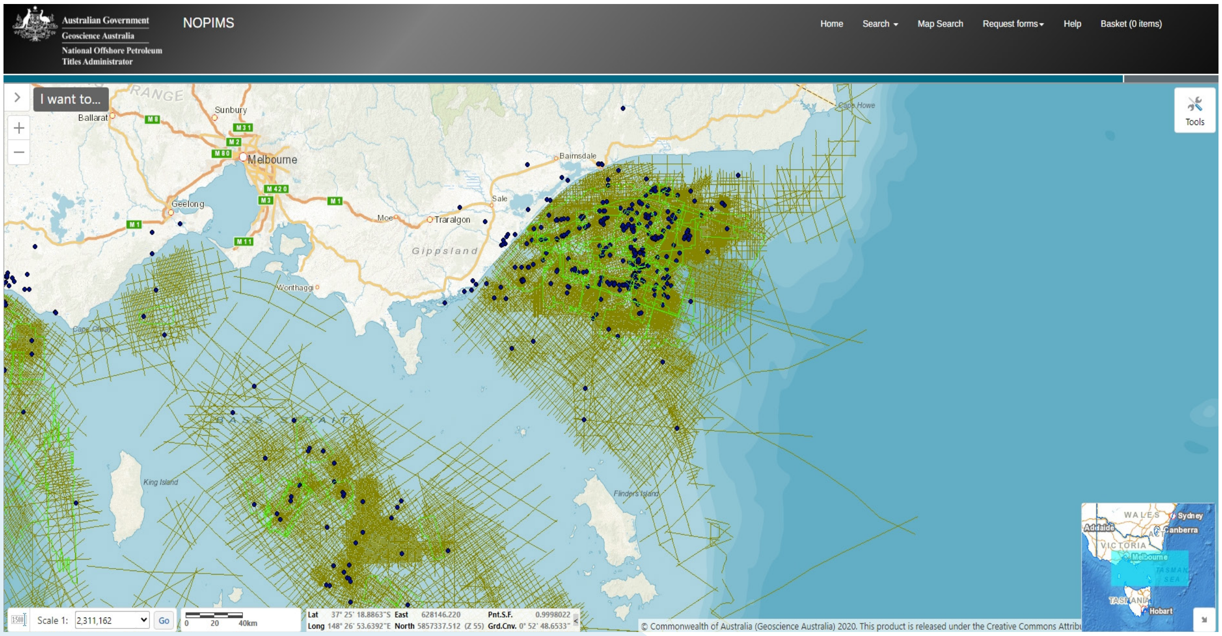
Source: European Marine Observation Data Network Map Viewer. Available at https://emodnet.ec.europa.eu/geoviewer/.

2. ECONOMY

Data collected by private companies may have value for purposes other than that for which they were originally collected, including for safe navigation, marine environment protection and other public goods. In almost all cases, the data will be protected by intellectual property rights requiring the consent of and, in some cases, financial compensation to their owner for access. Surveys by oil companies often include information that is valuable for safe navigation or may be valuable for the management or economic development of marine resources beyond the original exploration goals. Several models for providing access to these data have been developed, each dependent on applicable national legal frameworks. In some cases, a secondary industry may be developed to obtain commercial value from the resale of the data; in others, it may be necessary to provide exploration data to the State for public release after a statutory embargo period, such as in Australia for offshore petroleum data, where seismic and well data that are out of embargo are accessible through the National Offshore Petroleum Information System, as shown in figure III.

Figure III

Extract from the National Offshore Petroleum Information System portal

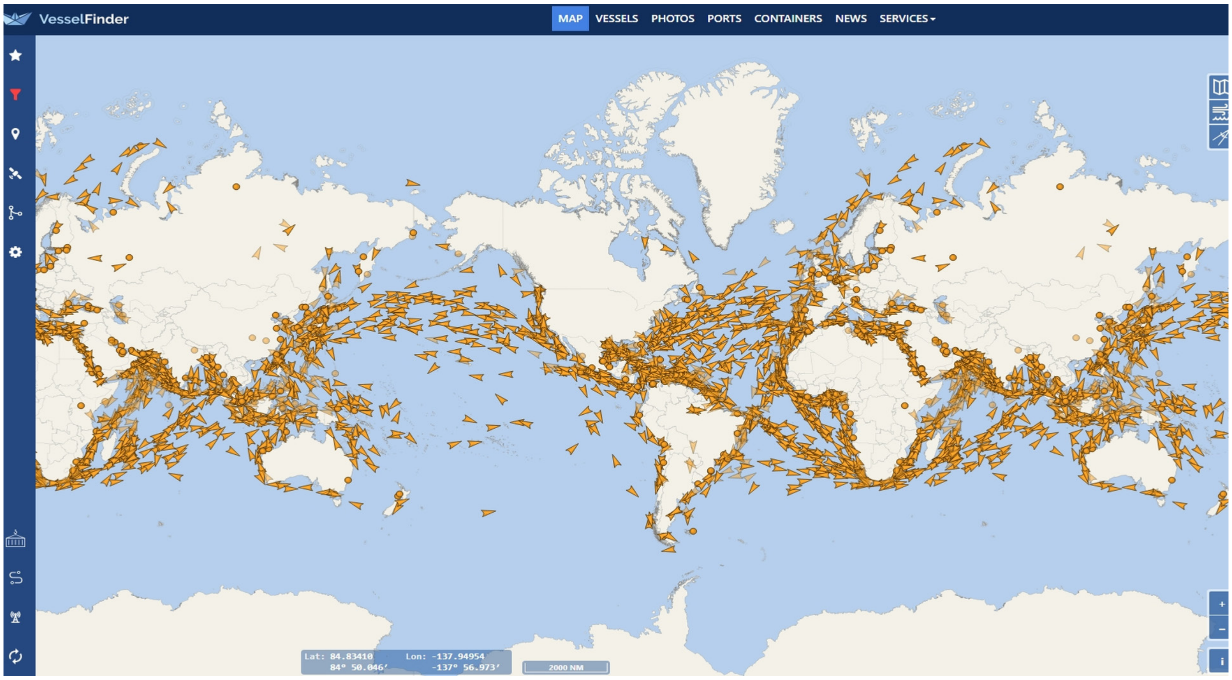


Source: Geoscience Australia, Australia, National Offshore Petroleum Information Management System NOPIMS. Available at www.ga.gov.au/nopims.

Shipping data, including ship positions and associated information, such as those reported through the automated identification system or the vessel monitoring system, are usually collected to monitor shipping and fishing activities in real time. The data continue to have value for marine planning and environmental management. Often the data are made fully available under a subscription service or are limited, through aggregation or anonymity, as shown in figure IV.

Figure IV

Example of a vessel tracking tool offering some services for free and others with paid subscription



Source: VesselFinder. Available at www.vesselfinder.com.

3. CULTURE

Wreck locations and underwater cultural heritage sites are other types of geospatial information for which the precise location cannot be publicized, owing to their cultural and environmental sensitivity. The exact locations of such sites cannot be released for fear of looting or excessive visitation, which could lead to the damage or destruction of the sites. An example of an online shipwreck database is provided in figure V.

Figure V

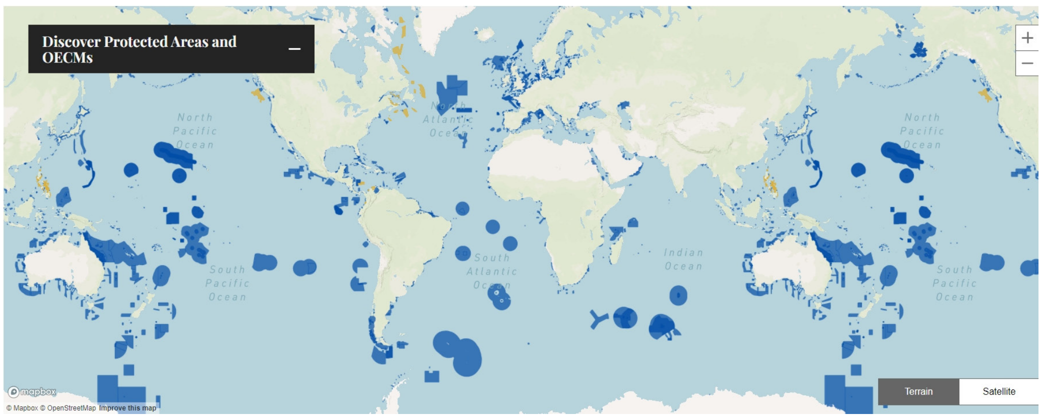
Example of an online shipwreck database

Source: The Wrecksite. Available at www.wrecksite.eu/wreck-search.aspx.

4. ENVIRONMENT

The exact locations and underlying designation information for marine protected areas can be difficult to access because they are managed by multiple organizations and individual States. The World Database on Protected Areas is a joint venture between UNEP and the International Union for Conservation of Nature, managed by the UNEP World Conservation Monitoring Centre. An example of an online protected areas database is provided in figure VI.

Figure VI
Example of an online protected areas database



Source: Protected Planet, "Discover protected areas and OECMS". Available at www.protectedplanet.net/en.

At the single point of access provided by Protected Planet, data from governments, non-governmental organizations, landowners and communities are brought together with monthly updates using standardized methodologies for processing and presentation. It is an example of the power of overcoming data and information restrictions for the reuse of content. It provides the basis for monitoring and reporting on progress towards achieving international environmental targets, such as the Aichi Biodiversity Targets and the Sustainable Development Goals, which would otherwise be restrictive and time-consuming to achieve.

The consequences of placing excessive restrictions on information access can be very high. Within a single project, there are risks associated with outdated marine data sets, costs are incurred for the acquisition of more accurate or higher-resolution data and more time is needed to find and then process information that is not standardized. If marine geospatial data and information are not centralized, some marine environment themes can be overlooked.

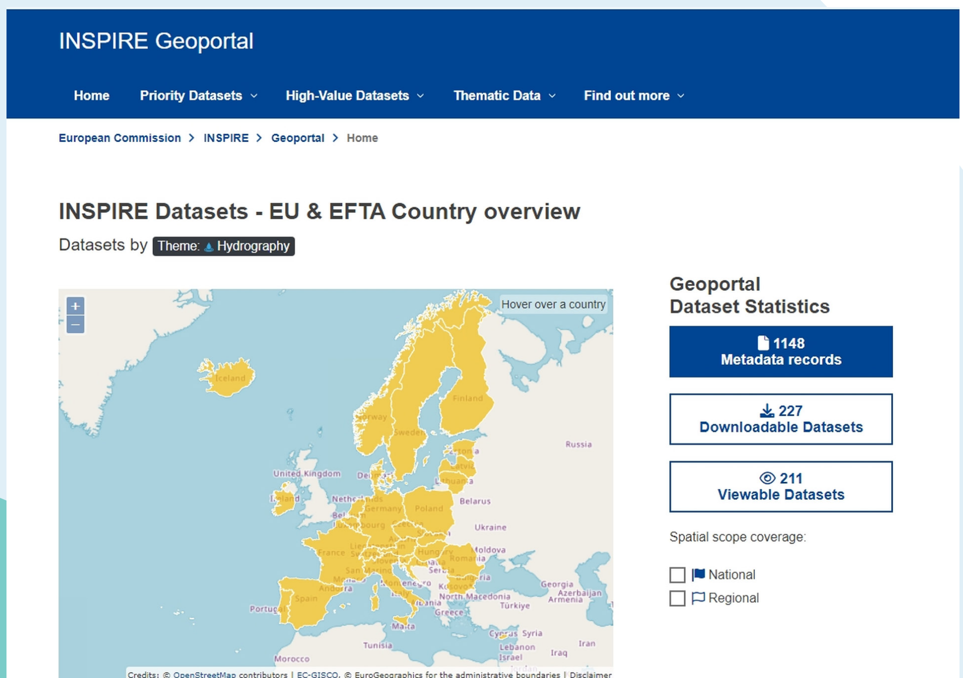
B. Managing restricted marine geospatial data and information and paths to access

In recent years there has been an concerted push worldwide to increase accessibility to geospatial data and information, including marine geospatial data and information, irrespective of the area of work and inclusive of the maritime environment. Some examples follow.

1. INFRASTRUCTURE FOR SPATIAL INFORMATION IN THE EUROPEAN COMMUNITY

The directive on Infrastructure for Spatial Information in the European Community, often known as INSPIRE, has been established to reduce the barriers to freely accessible online environmental data, in general, and marine geospatial data, in particular, in the European Union, and has delivered efficiency for all stakeholders working in a marine-related field. An extract from the INSPIRE geoportal is shown in figure VII.

Figure VII
Extract from the INSPIRE geoportal for hydrography

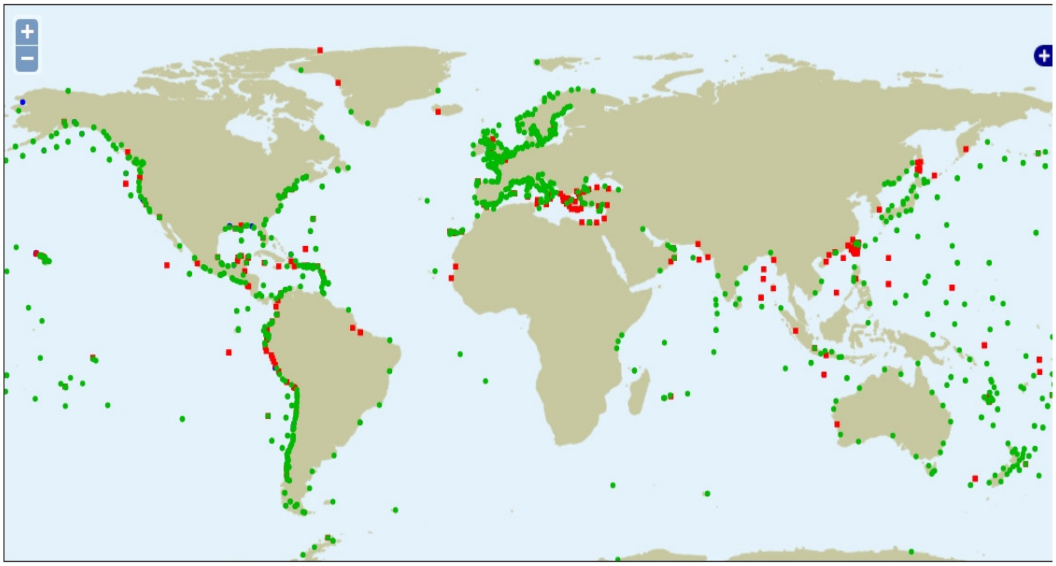


Source: European Commission, "Hydrography", INSPIRE Datasets – EU & EFTA Country overview. Available at https://inspire-geoportal.ec.europa.eu/srv/eng/catalog.search#/overview?view=themeOverview&theme=hy

2. SEA LEVEL STATION MONITORING FACILITY

The Sea Level Station Monitoring Facility, an extract of which is shown in figure VIII, provides information about the operational status of global and regional networks of sea level stations in real time and a display service for quick inspection of the raw data stream from individual stations.

Figure VIII
Extract from the Sea Level Station Monitoring Facility



Source: Flanders Marine Institute and Intergovernmental Oceanographic Commission, Sea Level Station Monitoring Facility. Available at www.ioc-sealevelmonitoring.org.

C. Licensing templates

Under strategic pathway 2[44] of the United Nations Integrated Geospatial Information Framework, a policy and legal framework has been established that is essential for instituting the effective, efficient and secure management and exchange of geospatial information. In that context, a policy and legal resource kit[45] has been developed. It includes such model legal instruments as an agreement, a policy and legislation that States and private entities can refer to and, where appropriate, adapt to their specific circumstances when implementing the Integrated Geospatial Information Framework, with a view to improving data-sharing and exchange at the national level.

44 See https://ggim.un.org/UN-IGIF/documents/SP2-Policy-and-Legal-23Feb2020-GLOBAL-CONSULTATION.pdf.

45 See Working Group on Policy and Legal Frameworks for Geospatial Information Management, Committee of Experts on Global Geospatial Information Management, *United Nations Integrated Geospatial Information Framework Policy and Legal Resource Kit* (New York, 2022).). Available at https://ggim.un.org/documents/UN-IGIF-Policy-and-%20Legal-Resource-Kit-Aug2022.pdf.

V. NEXT STEPS FOR MARINE GEOSPATIAL INFORMATION MANAGEMENT

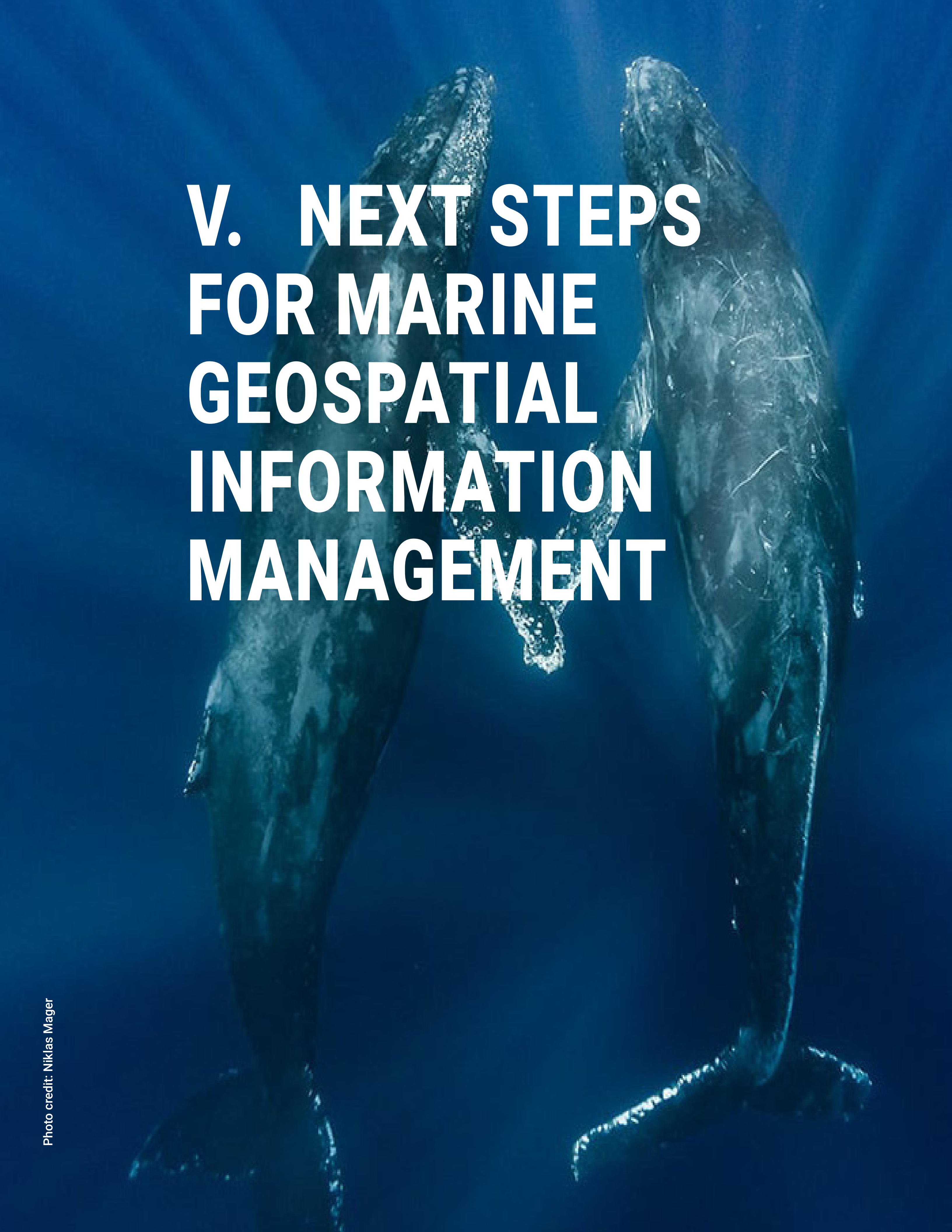


Photo credit: Niklas Mager

A. Initiatives to date

Initiatives in the past decade have demonstrated the benefits of open access to marine geospatial data and information. Improved access has led to increased demand and has driven innovation in marine geospatial data and information management, and intergovernmental organizations have successfully taken up the challenge of promoting and implementing the FAIR guiding principles. In addition, there is a growing archive of accessible reference standards that can be applied by all end users to define and structure their content. Global marine geospatial databases and access mechanisms are being developed, and international organizations are working together across domains to build synergies. As a result, there is greater presentation, functionality, interoperability and reuse of information, which helps to extract additional value on initial investments.

Although much progress has been made, there remains much work to be done, and it is important to maintain and build upon the momentum that has been achieved. Future challenges in responding to the increased pressures on the oceans will drive a need for greater volumes and variety of data. Consequently, continuous investment in infrastructure and tools for analysis will be required to create the products that are needed for decision makers to act.

The present publication, including the input of all information providers, has highlighted the critical conditions and some obvious next steps in the process of maintaining the momentum in the development of marine geospatial data and information management.

B. Availability

There is now greater acknowledgement of the importance of marine geospatial data and information availability, the findability of the data and information and associated access requirements that can minimize barriers to their reuse, including in areas outside the area of original collection.

As the desire to be able to share data and information widely continues to grow, the positive implications of findable marine geospatial data and information that have clear access rules, including licensing, are now starting to be reaped by a wider community.

As the barriers to sharing marine geospatial data and information continue to be reduced and, as a result, the presentation, use and associated added value of the information beyond the purposes for which the data were originally collected continue to be developed, the prevention of duplicative collection, processing and reporting continues to be refined. This is an area of marine geospatial data and information management that can be further developed in order to increase efficiency and maximize the use of the data and information.

A positive first step towards building a wider understanding of the scope of marine geospatial data and information lies in users being able to find data, even if they cannot immediately be accessed. The knowledge and understanding of exactly which marine geospatial data and information are present in the marine world will drive other steps forward by association; for example, unlocked marine geospatial data and information will allow the development of long-term trend-based assessments of features by extending or further reinforcing and refining existing baselines. Furthermore, the risk of duplicated effort is reduced.

The challenge of implementing an entire system of principles, in particular for large and complex existing data sets, for which retrospective work can be daunting, expensive and time-consuming, should not prevent a stepwise approach in the presentation of the data sets as part of a larger and longer-term ongoing strategic process. Ensuring that marine geospatial data and information are findable is itself a significant step towards increased data interoperability that can be achieved without unreasonable effort.

Photo: Evans Boudin

C. Dependency

The importance of and the reliance on marine geospatial data and information for decision-making will only continue to grow. More and more marine geospatial data and information are deemed to be needed, but the means to store them and the capacity for handling, processing and disseminating them need to be developed simultaneously. The prioritization and use of existing frameworks and strategies is the first step towards responding to that need.

There will always be a need for marine geospatial data and information that have not yet been recorded or acquired, for data and information that are better, often in terms of resolution and the ability to detect and identify smaller features, or that cover a different or wider geographic or temporal scope. That need stems from marine geospatial data and information being critical for decision-making, underpinning considerations and decisions made in the marine environment, and from accelerating technological developments and the increased availability of such marine geospatial data and information.

The extensive network of frameworks and strategies in the supply chain of marine geospatial data and information needs to be exploited further in order to maximize capacity at each level and share the requirements that those frameworks and strategies provide for. In that regard, the first task that can be undertaken is the identification and recording of all marine geospatial data and information that are currently available and being prepared, in order to create a marine geospatial information knowledge baseline that can be used for strategic decision-making.

D. Communication

Communication, within and among entities, from the local to the global levels, has been highlighted as an area for further improvement. When content is recorded and shared, an archive of marine geospatial data and information is created that can help to ensure the availability of records. The development and resulting integration of the data supply chain presents a huge opportunity to operators and users at all levels.

The increased awareness of the existing marine geospatial data is an initial expected output that can feed directly into the strategic response process of decision makers, resulting in a feedback loop in the consideration of data product development. As a result, the creation of data products on the basis of the interpreted expectations of users is minimized and direct communication is established. That process further reinforces the importance of the initial collection of marine geospatial data and helps to maximize their reuse and overall value.

E. Longevity

The longevity of marine geospatial data and information has justified their archiving, in order that future efforts can build upon historic, foundational work. Longevity safeguards content that is required for existing frameworks that would otherwise have a data expiry date, which helps to address data sustainability. Intergovernmental organizations can play a crucial role by offering data sustainability functions as a part of their data plans to preserve marine geospatial data and information.

F. Strategic investment

Broader deliverables include the more focused use of continually stretched resources through strategic investment. To achieve greater oversight and improve the use of resources, consideration should be given to data flows as an entire life cycle and the ways in which education and training directly feed into implementation activities. Further identification of common issues and responses by developing and sharing openly community tools can maximize the use of vital marine geospatial data and information management practices across the globe.

G. Sovereignty

It is helpful to ensure that marine geospatial data and information custodianship remains guided by those who have sovereignty and simultaneously ensure presentation for the collective benefit, taking into account the CARE Principles for Indigenous Data Governance. That approach is directly connected with maximizing capacity at each step of the process and the identification of the step that can benefit the most from strategic investment. Owners of marine geospatial data and information should be proponents of their own data from their own area and the associated increase in value to the community, both financially and from a knowledge perspective. They should curate the data and information, paying attention to the needs of and feedback from their immediate and wider audiences, which may use, and therefore increase the value of, the data and information. It should be emphasized that, although the sovereignty of marine geospatial data and information is important, data-sharing has often proved beneficial for all parties in the past.

H. Overall development

The developments in the management of marine geospatial data and information have demonstrated the potential ways in which good practices can increase the efficient use of resources at all levels, with intergovernmental organizations playing a central role. That trend is very encouraging, but it highlights the continued need to further develop marine geospatial data and information management in order to keep up with technological advances, to be fit to tackle future challenges and to provide the best base for decision-making at all levels.

I. Recommended action

The future of sustainable ocean governance will rely heavily on marine geospatial data and information to guide integrated planning and the achievement of marine-related goals. Three initiatives to consider when aiming to establish and maintain standardized geospatial data and information management practices that are compatible and interoperable with other data management systems globally and within and across organizations are as follows:

(a) Schedule of detailed publications on thematic topics, the first in a series of which could be on the physical geography, characteristics and processes of the ocean, with the topics for subsequent publications to be determined through the analysis of the results deriving from the implementation of the following two recommended actions;
(b) Catalogue of the marine geospatial data and information landscape, and the responsibilities of intergovernmental organizations, which will contribute significantly to responding to the knowledge gaps identified in the World Ocean Assessment and the implementation of the Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction;
(c) Survey of intergovernmental organizations to document the maturity of existing marine geospatial data and information management initiatives and to seek the identification of thematic areas for priority action.

Marine geospatial information management

Annex 1

2024

United Nations

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ANNEX I: MARINE GEOSPATIAL INFORMATION AND DATA TOPICS IN *THE SECOND WORLD OCEAN ASSESSMENT*

In its resolution 57/141, the General Assembly decided to establish a regular process under the United Nations for the global reporting and assessment of the state of the marine environment, including socioeconomic aspects, both current and foreseeable, building on existing regional assessments. The goal was to ensure a comprehensive overview of the ocean and the relationships between the ocean and humans, covering all environmental, social and economic aspects. *The First Global Integrated Marine Assessment* was published in 2016. It helped to establish a baseline and its conclusion was that many parts of the ocean had been seriously degraded and that, if the problems were not addressed, they would produce a destructive cycle of degradation in which the ocean could no longer provide many of the benefits on which humans rely. *The Second World Ocean Assessment* was published in 2021. Its scope was extended to the evaluation of trends and the identification of gaps. Among its conclusions was that the ability to measure and, therefore, understand the changes of the principal components of the marine environment is not equal across the planet. Spatial and temporal data gaps were identified in almost all components of the marine environment that were considered. The following is a summary of the spatial and temporal data gaps for each component of the marine environment included in *The Second World Ocean Assessment*.

I. State of the marine environment

A. Physical and chemical state of the ocean

The analysis in this section is based on chapter 5 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment contains an analysis of the current physical state of the oceans through seven climate change indicators: sea level, ocean circulation, sea temperature and ocean heat content, salinity, ocean acidification, dissolved oxygen and sea ice.

2. RELEVANCE

Monitoring those indicators over time and following their global patterns would provide valuable information on the impact of climate change and on the physical and chemical state of the ocean. The changes are closely related to trends in the state of biodiversity and marine habitats and spatial and temporal patterns of extreme climate events.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

(a) Sea level

Currently, global mean and regional sea levels are well documented, mainly by satellites measuring the topography of the sea surface, known as satellite altimetry missions. That is not the case for coastal sea levels, which are highly undersampled by tide gauges. In addition, coastal zones are not surveyed by conventional satellite altimetry missions because the proximity of the land adversely affects the accuracy of the measurements obtained by the satellites. Investing in reprocessing of the data acquired by conventional satellite altimetry missions and the systematic use of new synthetic aperture radar technology will facilitate the estimation of sea level changes very close to the coast.

(b) Ocean circulation

Although the overall current ocean observation network provides a large amount of spatial and temporal data on ocean circulation globally, data are not as readily available for coastal regions, marginal seas and deep ocean regions below 2,000 m. In addition, uncertainties about ocean circulation arise from the short timespan of direct, continuous measurements. Consequently, there is a need to design an observation system that incorporates a mixture of observation technologies adapted to the various operating environments.

(c) Sea temperature and ocean heat content

As is the case with ocean circulation measurements, the understanding of sea temperature and ocean heat content could be improved with longer, direct, continuous measurements. To achieve that goal, investment is needed in the development of a global long-term surface energy flux observation system.

(d) Salinity

Temporal and spatial coverage with modern observations, dating back to 2008, inevitably allowed for a better understanding of salinity change. The short timespan of modern data availability, however, affects the long-term historical assessment and modelling of changes in salinity. Maintaining and upgrading the existing observation systems and expanding the observed geographical area, with a view to improving the current understanding of salinity change and the related impacts on marine ecosystems, should, therefore, be the goal in the future.

(e) Ocean acidification

National and international monitoring of carbonate chemistry over the past decade contributed to a better understanding of the status and impact of ocean acidification from the local to the global level. The variability of carbonate chemistry across various depths, distance from continents, owing to land influence, upwelling regimes, freshwater and nutrient input and latitude, and the time of emergence of the signal varying from 8 to 15 years for open ocean sites and from 16 to 41 years for coastal sites, however, require a commitment to global long-term observational records, especially in the coastal zone, where most commercially and culturally important marine resources are found.

(f) Dissolved oxygen

Dissolved oxygen has been observed with sufficient accuracy since the early 1900s globally. It is noted in *The Second World Ocean Assessment* (vol I, p.331), however, that there is a need to monitor environmental variables, including dissolved oxygen, in areas near the edge of coral species niches, near the aragonite saturation horizon, in basins where temperatures are high, such as the deep Mediterranean, and where cold water coral ecosystems are threatened by the cumulative stressors of human activities.

(g) Sea ice

Although monitoring of the geophysical parameters of sea ice by satellite is improving, local observations to validate those of satellites are lacking, both in the Arctic and in the Antarctic. There is a need to improve local measurements of snow on sea ice and the thickness of sea ice to improve the understanding of the physical processes in the polar regions.

II. Biodiversity of the main taxa of marine biota

A. Plankton (phytoplankton, zooplankton, microbes and viruses)

The analysis in this section is based on chapter 6A of *The Second World Ocean Assessment*.

1. INTRODUCTION

Single-celled organisms are immensely significant as a fundamental component of marine life. They collectively contribute to approximately 50 per cent of primary production on Earth, making them essential for sustaining ocean biodiversity and regulating the planetary carbon cycle. Among the planktonic community, marine phytoplankton, including diatoms and picoplankton (less than 2 µm in size), play a critical role in marine primary production, driving marine food webs and supporting various marine species.

2. RELEVANCE

Understanding the dynamics of plankton diversity and productivity is crucial for comprehending the functioning of marine ecosystems and their services. Plankton not only support marine biodiversity but also sustain fisheries by forming the foundation of food chains. Moreover, the biological pump facilitated by plankton assists in sequestering atmospheric carbon dioxide, helping to mitigate the impact of climate change. A better understanding of the health and abundance of the microscopic organisms will provide valuable insight into the state of marine ecosystems, enabling informed conservation efforts and sustainable management of marine resources in the face of ongoing environmental changes.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Despite the vital role of plankton in marine ecosystems, the current status of global ocean observation lacks dedicated monitoring mechanisms for plankton diversity. That deficiency highlights the necessity for an international, integrated observation system that is focused on ocean life, in particular plankton, as part of the broader Global Earth Observation System of Systems. Presently, such challenges as undersampling and the discovery of cryptic species through metagenomics hinder the accurate assessment and understanding of plankton diversity. Overcoming the challenges and improving global ocean observations are crucial steps in effectively monitoring plankton diversity and productivity.

B. Marine invertebrates

The analysis in this section is based on chapter 6B of *The Second World Ocean Assessment*.

1. INTRODUCTION

Marine invertebrates constitute a vital component of marine ecosystems, serving as integral food sources and contributing to ecological balance. The organisms face multiple threats, such as climate change, pollution and overexploitation.

2. RELEVANCE

Marine invertebrates serve as a crucial food source for various marine species, supporting global fisheries and food security for coastal communities. In addition, their presence or decline has a great impact on marine biodiversity, influencing the health of coral reefs and other critical ecosystems. Safeguarding marine invertebrates is, therefore, essential for ensuring resilient marine ecosystems and the well-being of coastal communities.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

In recent years, efforts have been made to enhance the understanding of marine invertebrates, but challenges persist. From 2012 to 2019, 10,777 new marine benthic invertebrate species were described, primarily in the Mollusca and Arthropoda phyla. Notably, the North Atlantic Ocean and South Pacific Ocean, including the Coral Sea, were home to the highest number of recorded species. Despite that progress, knowledge gaps remain, in particular in tropical regions, hindering a comprehensive assessment of global marine invertebrate diversity. Data collection is further complicated by the various factors affecting marine invertebrates. Climate warming has led to distribution shifts, affecting marine communities of the Arctic, North Atlantic and Pacific Oceans. The introduction of invasive species disrupts ecosystems and poses additional threats to native invertebrates. Furthermore, pollution from diverse sources contributes to low oxygen conditions, diminishing species diversity in affected areas. To address those challenges, data-collection efforts must be improved. Long-term monitoring of marine areas, in particular in vulnerable habitats, is essential for understanding population trends and assessing the effectiveness of conservation measures. Prioritizing taxonomic identification and baseline biodiversity studies will help to bridge knowledge gaps, leading to more informed conservation strategies.

C. Fishes

The analysis in this section is based on chapter 6C of *The Second World Ocean Assessment*.

1. INTRODUCTION

Fish biodiversity is a fundamental component of oceans: it contributes to the overall health and stability of marine ecosystems and directly affects human communities and economies that rely on fisheries and related industries.

2. RELEVANCE

The collection of marine fish biodiversity data is highly relevant for environmental monitoring, fisheries management, conservation and economic decision-making. Biodiversity data are essential for effective fisheries management. Sustainable fisheries rely on the knowledge of fish species abundance, migration patterns and habitat preferences. With adequate data, stakeholders can implement appropriate measures to prevent overfishing and ensure the long-term viability of fish stocks. Protecting vulnerable fish species is crucial not only for their survival but also for maintaining the ecological balance of marine ecosystems.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Significant progress has been made in the collection of marine fish biodiversity data. Taxonomic studies have led to the discovery and description of numerous new fish species, contributing to a more comprehensive understanding of fish diversity. In addition, advances in phylogenetic studies have improved knowledge of the evolutionary relationships among fish species. The availability of global databases, such as the Ocean Biodiversity Information System, has revolutionized the study of fish occurrence and distribution. Vast amounts of occurrence records from various sources are compiled in the databases, enabling researchers to study species distribution and biogeography on a global scale. Many marine fish species have been assessed for their conservation status, providing valuable insights into which species require urgent protection measures. Moreover, technological innovations have significantly enhanced data collection in challenging marine environments. Sampling technologies, such as remotely operated vehicles and autonomous underwater vehicles, have enabled researchers to explore deep-sea habitats and collect valuable data on previously inaccessible species. Satellite tagging has provided insights into fish migration patterns and behaviour.

Despite those advances, however, critical gaps in data collection persist. Taxonomy and systematics remain ongoing challenges, given that there are likely many undiscovered fish species, in particular in remote and deep-sea regions. Consequently, taxonomic efforts must continue to ensure a comprehensive understanding of marine fish diversity. Furthermore, to address complex ecological questions, more integrated research efforts are necessary. Combining data from multiple sources, such as genetics, oceanography and ecology, will enable scientists to predict the responses of fish species to multiple stressors, including climate change and human activities.

D. Marine mammals

The analysis in this section is based on chapter 6D of *The Second World Ocean Assessment*.

1. INTRODUCTION

There are 132 known surviving species of marine mammals, including cetaceans, pinnipeds, sirenians, otters and the polar bear. They have varied habits, ranging from those with multiple discrete local populations, as is the case for some dolphin species, to those that are endemic to a specific ecoregion, such as freshwater dolphins. Marine mammal populations face numerous threats, such as by-catch in fisheries, habitat alteration, pollution, anthropogenic noise and climate change. Understanding the threats and their impact on marine mammals is crucial for devising appropriate conservation strategies.

2. RELEVANCE

Data collection is of utmost importance in marine mammal conservation. It aids in understanding population dynamics, threats and ecological interactions, leading to effective management and policy development.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Better data-collection and management efforts have led to improved conservation of marine mammal populations. The impact of climate change on marine mammal populations and their habitats, however, requires ongoing research and data collection to inform future conservation strategies. Furthermore, data collection plays a critical role in understanding the consequences of changes in marine mammal populations on ocean processes, including in the spatial transfer of nutrients and carbon, human communities and the economy. Continued efforts in cooperative data collection and related research are essential for ensuring the long-term survival and well-being of marine mammal species and the ecosystems that they inhabit.

E. Marine reptiles

The analysis in this section is based on chapter 6E of *The Second World Ocean Assessment*.

1. INTRODUCTION

The *World Ocean Assessment* is focused on assessing the conservation status of marine turtles, sea snakes and marine iguanas. Marine reptiles face numerous threats, including by-catch, targeted harvesting, marine pollution, habitat loss, coastal development, disease and climate change.

2. RELEVANCE

Understanding the reproductive biology, foraging habitats, demographics, disease pathogenesis, geographical distribution, movements, habitats, resilience to disturbances and responses to threats of marine reptiles is crucial. Marine reptiles face threats from by-catch, pollution, habitat loss, coastal development, disease and climate change, and, therefore, a well-informed approach is necessary in order to strike a balance between, on the one hand, economic growth through tourism, and on the other, conservation efforts, and to safeguard these unique species and their ecosystems.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Advances in data-collection efforts and related research have led to significant changes since the first World Ocean Assessment in the status of marine reptiles on the IUCN Red List of Threatened Species, such as the shift of the loggerhead turtle from “endangered” to “vulnerable” and the reclassification of two sea snake species from “critically endangered” to “data deficient”. Despite the advances, there are still significant knowledge gaps, in particular in relation to the effect of known threats, that hinder effective conservation efforts. Building capacity and implementing long-term monitoring initiatives are paramount to address the gaps and inform conservation strategies.

F. Seabirds

The analysis in this section is based on chapter 6F of *The Second World Ocean Assessment*.

1. INTRODUCTION

Seabirds, defined as bird species heavily reliant on the marine environment for part of the year, play a crucial role in marine ecosystems as top predators. They consume biomass comparable to all fisheries combined. Seabirds inhabit various oceanic regions, connecting various marine systems and ocean basins. There are 359 identified species of seabirds, categorized into six orders and 12 families. They are relatively well studied compared with other marine taxa, with several assessments documenting their status and trends over the years.

2. RELEVANCE

The global conservation status of seabirds has deteriorated since the first *World Ocean Assessment* was published in 2016. By 2020, 31 per cent of species were threatened with extinction, up from 28 per cent in 2010. Fishing-related pressures, such as by-catch and prey depletion, have increased the number of affected species, although pollution is affecting fewer species. Invasive alien species and climate change continue to threaten seabird populations, similar to the situation in 2010.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

There has been a comprehensive review of the threats affecting seabird species, leading to changes in their conservation status. Some species have experienced a worsening outlook and are now categorized at a higher risk, while others are considered to be at a lower risk, owing to greater knowledge rather than genuine improvements in their status. Data-collection efforts have improved the understanding of the impacts of such threats as fishery by-catch and prey depletion by fishing, and of the decrease in marine pollution due to reduced oil spills. Emerging threats, however, including marine plastics and the complex consequences of climate change on seabird populations, require further study. To address those challenges and make informed decisions, the remaining knowledge gaps in the demography, distribution and population trends of seabirds, in particular smaller species, must be bridged. To achieve that goal, a greater focus on capacity-building efforts for monitoring, research and assessment will be crucial.

G. Marine plants and macroalgae

The analysis in this section is based on chapter 6G of *The Second World Ocean Assessment*.

1. INTRODUCTION

Mangroves, salt marsh plants, seagrasses and macroalgae (seaweeds) are vital forms of vegetation and components of coastal ecosystems, providing numerous ecological services and supporting marine biodiversity.

2. RELEVANCE

Mangroves, salt marshes and seagrasses act as critical nursery habitats for marine organisms, enhance water quality and protect coastlines from erosion and storms. Macroalgae form extensive and productive coastal habitats, supporting numerous marine species and providing food for various organisms, including humans. The loss of marine plant species can have severe impacts on human communities and economies.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Despite advances in genomics, taxonomic and systematic studies of marine plants are lacking in many regions. Enhancing human and infrastructure capacities is vital for monitoring and conserving marine biodiversity, in particular in small island States and archipelagic countries. Further research is needed to assess the impact of human activities and climate change on marine plant populations and ecosystems.

III. State of biodiversity in marine habitats

A. Intertidal zone

The analysis in this section is based on chapter 7A of *The Second World Ocean Assessment*.

1. INTRODUCTION

The intertidal zone, located where the land meets the sea, encompasses a diverse range of habitats along coastlines worldwide. The unique zone experiences regular exposure and immersion, owing to tides, making it a crucial interface between terrestrial and marine ecosystems. Rocky shores, sandy beaches, mangroves, coral reefs and tidal flats are among the various environments found in the intertidal zone. Due to its accessibility, the zone plays a pivotal role in human activities and interactions, making it of particular importance for subsistence and small-scale fisheries and harvesting.

2. RELEVANCE

The significance of the intertidal zone extends beyond its ecological role. It is located at the forefront of human influence on the oceans. Human activities, such as deforestation and coastal modification, have a direct impact on the intertidal zone, and climate change indirectly affects it. Coastal development and urbanization alter intertidal habitats, posing risks to coastal communities and marine species. As sea levels rise, intertidal habitats face the threats of reduction and coastal squeeze, affecting both ecosystems and human well-being.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Despite the importance of the intertidal zone, there are still significant knowledge gaps and limited taxonomic infrastructure, in particular in developing countries. Baseline data on intertidal ecosystems require improvement through comprehensive studies and enhanced data-collection efforts. Understanding the impact of human activities and climate change on intertidal habitats requires accurate and comprehensive data, which can be challenging to obtain in less developed regions. Addressing the limitations in data collection is crucial for the effective conservation and sustainable management of intertidal ecosystems and their long-term health and resilience.

B. Biogenic reefs and sandy, muddy and rocky shore substrates

The analysis in this section is based on chapter 7B of *The Second World Ocean Assessment*.

1. INTRODUCTION

Biogenic reefs and sandy, muddy and rocky shores are indispensable components of coastal ecosystems, supporting biodiversity and providing vital ecosystem services. The habitats exist on coastlines worldwide and are interconnected with diverse ecosystems, including coral reefs, estuaries, mangroves and salt marshes.

2. RELEVANCE

Biogenic reefs and sandy, muddy and rocky shores are of immense significance in coastal environments, owing to their rich biodiversity and the essential ecosystem services that they provide. The habitats perform critical functions, such as water filtration, nutrient cycling and coastline protection, which have a direct impact on human well-being and support livelihoods. With over 60 per cent of the global population living in coastal areas, such environments are economically relevant, facilitating tourism, recreational activities and artisanal and commercial fishing and serving as aesthetically pleasing destinations. They are increasingly vulnerable to various stressors, however, including pollution, coastal urbanization and the adverse effects of climate change, posing significant challenges to their health and functioning.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Although biogenic reefs and sandy, muddy and rocky shores are recognized for their ecological importance, there are still notable knowledge gaps, in particular in less developed regions. Not enough spatial and temporal data and information are available to anticipate medium-term or long-term scenarios with accuracy. Data are particularly scarce across some regions, such as the South Atlantic, the wider Caribbean and the western Pacific.

C. Atoll and island lagoons

The analysis in this section is based on chapter 7C of *The Second World Ocean Assessment*.

1. INTRODUCTION

Low-lying tropical coral reef and atoll islands and their associated lagoon systems are geologically young features, shaped by fluctuations of the sea level, biological sediment production and oceanic and atmospheric conditions. With their low-lying nature, small extent and exposure to marine conditions, the islands are vital for subsistence communities which are heavily reliant on the surrounding reefs for daily food security.

2. RELEVANCE

The relevance of atoll islands lies in their susceptibility to diverse environmental threats and the impact of the resulting changes on human communities. Urban atoll islands are increasingly dependent on engineering solutions to mitigate environmental risks, and rural island communities rely on the health and productivity of surrounding marine and coastal ecosystems. Major challenges include climate change, rising sea levels, erosion, storms, reef degradation and lagoon pollution, all of which significantly affect the islands and their inhabitants.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

There is little information on the way reef processes respond to changes in individual and compounded climate drivers as they change. Geographical variability in shoreline erosion and inundation is observed, but the causes of those spatial patterns are poorly understood, which largely precludes any forecasting of the behaviour of particular locations.

D. Tropical and subtropical coral reefs

The analysis in this section is based on chapter 7D of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment provides an update on the status of tropical and subtropical coral reefs in several regions, and contains a description of their steady degradation, including widespread mortality of corals from global marine heatwave events and declines in biodiversity.

2. RELEVANCE

Tropical and subtropical coral reefs are vital ecosystems that support diverse marine species and play a crucial role in coastal protection. They are important sources of income, including in the fishing and tourism industries, and are a basis for sociocultural identity. Despite their ecological and economic significance, reefs face severe threats, primarily from climate change and anthropogenic activities. With coral reefs projected to face functional extinction by 2050 if current trends persist, the loss of coral reefs will affect the ability to achieve any of the Sustainable Development Goals. The monitoring of reef health and the effectiveness of management tools are crucial to informing efforts to improve reef resilience and combating their degradation.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Progress has been made in addressing significant knowledge gaps that were reported in *The First Integrated Marine Assessment*, including understanding the responses of corals and coral-dependent species to climate change and the spatial extent of mesophotic coral reefs. Currently, there are knowledge gaps around the responses of reef communities to climate change; the socioeconomic value of coral reefs; the effectiveness of management tools to improve reef resilience; and the distribution, biodiversity and ecological function of mesophotic coral reefs. Although new technologies have been developed to monitor coral reef systems, there is limited local capability to use them.

E. Cold water corals

The analysis in this section is based on chapter 7E of *The Second World Ocean Assessment*.

1. INTRODUCTION

Cold water corals are globally distributed and play a vital role in supporting diverse marine habitats. Their ecosystems are intricately connected with the open ocean through benthic-pelagic coupling, contributing to the deep-sea food web and nutrient cycling.

2. RELEVANCE

Cold water coral ecosystems are relevant to marine biodiversity, sustainable fisheries, carbon sequestration and human well-being. They serve as habitats and nurseries for commercially exploited fish stocks, contributing to sustainable fishing practices. In addition, cold water corals offer valuable marine genetic resources and act as carbon sinks, sequestering carbon from the atmosphere and mitigating the impacts of climate change. Their conservation is vital for protecting vulnerable marine ecosystems and achieving Sustainable Development Goals related to marine conservation, food security and economic benefits for countries relying on marine resources.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

The data-collection efforts relating to cold water corals are steadily improving, but substantial knowledge gaps persist. Recent advances in predictive habitat modelling have led to new discoveries, identifying populations of cold water corals in various regions, such as the Antarctic continental shelf, North Pacific low pH waters and the Moroccan Atlantic continental margin. The use of long-term observatories has enhanced the understanding of cold water coral habitats at local and regional scales, emphasizing the importance of sustained ocean monitoring. Despite progress, several challenges hinder data collection and research on cold water corals. The remoteness and complexity of the deep-sea environment make data-gathering time-consuming and expensive. Standardizing data-collection protocols and increasing cross-sectoral collaboration could improve data comparability and efforts to bring use of data to scale.

F. Estuaries and deltas

The analysis in this section is based on chapter 7F of *The Second World Ocean Assessment*.

1. INTRODUCTION

Estuaries and deltas are unique habitats for diverse marine and coastal organisms. They hold great importance for human populations, offering resources for recreation, food provisioning and water supply.

2. RELEVANCE

Estuaries and deltas are highly productive systems, with variable gradients in salinity, nutrients and other factors, influenced by natural events and human-driven activities. Despite human perturbations, the environments support biodiversity and various ecosystems, such as mangroves, salt marshes, seagrass meadows and intertidal zones. They play a crucial role in sustaining commercial and subsistence fisheries, tourism and recreation, contributing significantly to the global economy (estimated at over $6.1 trillion in 2014). The mouths of rivers act as conduits for freshwater, nutrients, sediments and pollutants, making them essential for marine and coastal ecosystems.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Advances have been made in observation systems, such as satellites, global observation networks and buoys, designed to capture rapid changes in the environmental conditions of estuary and delta environments. There remain challenges in managing land use in estuaries and deltas, in particular in predicting future extreme events and the effects of rapid human interventions. More data are needed to understand coastal wetland conservation in areas where it can be most beneficial or might alleviate the need for engineered protection works. Improving monitoring and investing in scientific research will enhance the understanding of changing ecosystem services and their implications for human well-being.

G. Seagrass meadows

The analysis in this section is based on chapter 7G of *The Second World Ocean Assessment.*

1. INTRODUCTION

Seagrasses are marine flowering plants that inhabit coastal waters. Seagrass meadows have experienced alarming declines, primarily from coastal development, land reclamation, deforestation, pollution and overfishing.

2. RELEVANCE

Many socioecological systems rely on healthy seagrass meadows to support a multitude of important ecosystem services. The decline and loss of seagrass meadows pose significant challenges, leading to the degradation of fishing grounds, nursery areas and erosion control, with coastal communities facing adverse effects of storm surges, erosion and flooding. In addition, seagrass ecosystems make important contributions to marine carbon sequestration, holding promise as a vital tool for mitigating the impacts of climate change. Further understanding of the biology, ecosystem function, threats, rehabilitation, and restoration, monitoring and management tools for seagrass meadows is essential for their effective management and to realize their potential to provide diverse ecosystem services.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Although the general awareness of seagrass and the important ecosystem services it offers is improving, there is a lack of spatial and temporal data for many areas. Seagrass distribution maps must be more detailed, and there is currently no repository to share information at ecologically relevant scales. In addition, there are knowledge gaps in sociocultural and socioeconomic research. Technological advances, such as remote sensing and modelling, together with interdisciplinary approaches, will broaden the understanding of the complex interactions among seagrasses and their environment and encourage the identification of potential solutions to prevent further loss.

H. Mangroves

The analysis in this section is based on chapter 7H of *The Second World Ocean Assessment*.

1. INTRODUCTION

Mangroves are found across tropical and subtropical regions, are important ecosystems at the interface of sea and land, and are home to 73 recorded species and hybrids.

2. RELEVANCE

Mangroves provide valuable goods and services, such as seafood, timber, shoreline protection, carbon sequestration and waste bioremediation, and hold cultural significance for local communities. They face significant threats, making them one of the most endangered ecosystems globally. Human activities have led to the disappearance of over a quarter of the original mangrove cover. Certain conservation initiatives, rehabilitation efforts, natural regeneration and climate-induced expansion, however, have shown positive results in some areas. Further research on the sustainability and interrelationships of habitats and between mangroves and catches of marine fishing resources will increase the capabilities of coastal managers and empower local communities to conserve mangroves more effectively.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Various technological advances have improved mangrove distribution data on the global scale, with satellite data being a primary approach for assessment. Cloud computing platforms have made it possible to estimate more reliably local, regional and global mangrove cover and changes over time. There remains, however, a lack of reliable surveys on the status of mangroves at the global and regional scales, and of standardization of methods for assessing mangroves. Further research and capacity-building are necessary in order to standardize assessment methods and understand the interconnectivity between mangroves and adjacent coastal environments.

I. Salt marshes

The analysis in this section is based on chapter 7I of *The Second World Ocean Assessment*.

1. INTRODUCTION

Salt marshes, which are dynamic intertidal coastal systems that are regularly flooded with salt or brackish water, thrive on every continent except Antarctica. These habitats are dominated by salt-tolerant plants adapted to tidal immersion.

2. RELEVANCE

Found more commonly in temperate climates than subtropical or tropical regions with mangrove forests, salt marshes play a pivotal role in providing critical ecosystem services. They safeguard coastlines, prevent erosion, recycle nutrients and offer vital habitats for numerous species, including birds, fishes, molluscs and crustaceans. Their ability to sequester carbon dioxide as blue carbon sinks renders them crucial players in mitigating the impact of climate change.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Remote sensing techniques and surface elevation tables have been used in recent studies to monitor marsh accretion and loss rates. Knowledge gaps persist, however, necessitating increased spatial and temporal data-collection and capacity-building efforts to safeguard these vital coastal ecosystems.

J. Continental slopes and submarine canyons

The analysis in this section is based on chapter 7J of *The Second World Ocean Assessment*.

1. INTRODUCTION

Continental slopes are regions where the seafloor gradually deepens from the shelf edge to the upper limit of the continental rise. Steep-walled canyons are often found in these areas, contributing to habitat heterogeneity and biodiversity.

2. RELEVANCE

Slopes and canyons offer essential ecosystem services, such as carbon sequestration, nutrient recycling, fisheries and waste disposal. In addition, interest is growing in mining non-renewable resources from these areas. Furthermore, the sediment records found in the continental slope serve as a unique paleoecological archive, providing insights into historical deep-sea biodiversity dynamics.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Deep-sea environments remain poorly explored: most canyons and slopes remain uninvestigated, in particular those on the margins of developing countries. Some 66 per cent of the continental slope seabed bathymetry from 200 to 1,000 m and 72 per cent from 1,000 to 3,000 m remain unmapped, and an even larger area of the seafloor has never been surveyed for biology. Furthermore, there is a notable disparity in knowledge and technology across different regions.

K. High-latitude ice

The analysis in this section is based on chapter 7K of *The Second World Ocean Assessment*.

1. INTRODUCTION

In the *World Ocean Assessment* “high-latitude ice” is used as a generic term for a variety of critically important high-latitude marine habitats, which include ice shelves, pack ice, sea ice and the highly mobile ice edge. High-latitude ice habitats are characterized by high, but geographically variable, declines in the extent of sea ice resulting from climate change. In *The Second World Ocean Assessment* the coverage of high-latitude sea ice environments was extended to include habitats associated with icebergs and ice shelves.

2. RELEVANCE

Ice shelf and iceberg habitats provide unique marine signatures and have an impact on the surrounding ocean that is different from that of sea ice. Melting icebergs input nutrients and trace elements, creating productive ecosystems. Ice shelf decay and iceberg grounding have negative impacts on the environment, affecting coastal benthic ecosystems and marine organisms. In addition, the decreasing amounts of sea ice will reduce local community access to subsistence hunting opportunities. At the same time, the decreasing sea ice extent in the

Arctic provides increased opportunities for human activities, such as fishing, navigation and hydrocarbon exploration.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

The inaccessibility of the high latitudes means that the ice habitat remains relatively poorly understood, with limited understanding of the three-dimensional nature of ice habitats, the range and number of species within them and their spatial and temporal variability. Much analysis has been derived from remote sensing, with new satellite systems promising further knowledge. Ensuring universal access to new data produced by observation platforms will be vital to addressing knowledge and capacity gaps.

L. Seamounts and pinnacles

The analysis in this section is based on chapter 7L of *The Second World Ocean Assessment*.

1. INTRODUCTION

Seamounts, submerged volcanoes rising above the seafloor, cover up to 20 per cent of the deep seafloor and have a unique topography and physical structure.

2. RELEVANCE

Seamounts are hotspots of biodiversity and endemic species, providing significant ecosystem services. They support rich benthic communities and commercial fisheries. Limited sampling, however, hinders the understanding of their ecological importance and vulnerability to threats.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Recent research programmes have helped to improve knowledge of seamount ecosystems, including their effects on circulation, primary productivity and species distribution. Given that few seamounts have been surveyed globally, however, there are major gaps in the understanding of biodiversity scales and patterns on seamounts and their resilience to climate change and human activities. More comprehensive data-collection efforts are needed to fill knowledge gaps.

M. Abyssal plains

The analysis in this section is based on chapter 7M, of *The Second World Ocean Assessment*.

1. INTRODUCTION

The abyssal plains, located at a water depth of 3–6 km, cover about 58 per cent of the surface of the Earth. They mainly comprise vast areas of seafloor plains and are covered in generally fine sediments, punctuated by sporadic hard substrate at topographic highs in the form of knolls, seamounts, mid-ocean ridges and island arcs, and by lows in the form of valleys and deeper trenches. They are characterized by cold temperatures, high hydrostatic pressure and limited food availability.

2. RELEVANCE

Abyssal environments mainly support the processes that drive deep-sea and global ecosystems and the global climate system. They serve as a biological pump, transferring carbon and nutrients from surface waters to the deep sea. Few abyssal services could directly benefit humans, but the most significant are mineral resources.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Data-collection efforts in abyssal ecosystems have improved in recent years, but significant knowledge gaps still exist. Large areas of the abyssal plains remain unsampled. Where they have been sampled, taxonomic and biodiversity information remains limited, hindering environmental impact monitoring and the development of effective conservation measures. Data and information about the spatial and temporal distribution and patterns of species and their resilience to climate and human stressors in the abyssal plains are limited. The lack of data is further compounded by the fact that this vast expanse is almost entirely located in areas beyond national jurisdiction.

N. Open ocean

The analysis in this section is based on chapter 7N of *The Second World Ocean Assessment*.

1. INTRODUCTION

The open ocean, or the pelagic zone, consists of the epipelagic zone (down to a depth of 200 m), the mesopelagic or twilight zone (at 200–1,000 m depth), the bathypelagic zone (at 1,000–4,000 m), which comprises almost 75 per cent of the ocean volume, the abyssopelagic zone (at 4,000–6,000 m) and the hadalpelagic zone (deeper than 6,000 m).

2. RELEVANCE

The open ocean is essential for marine ecosystem goods and services and has great potential for mineral energy and living resources.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Although the epipelagic zone has been extensively studied, and spatial and temporal data on mesopelagic ecosystems are improving, very little is known about organisms from the deeper zones. The deeper pelagic ocean is significantly underobserved and undersampled. The main knowledge gaps relate to the open ocean ecosystems and the impact of physical drivers on the biodiversity found in them and the vertical migration of organisms between the deeper and upper ocean. More basic information, such as traditional taxonomy, must be collected about species that live in those environments.

O. Ridges, plateaux and trenches

The analysis in this section is based on chapter 7O of *The Second World Ocean Assessment*.

1. INTRODUCTION

Mid-ocean ridges comprise a system that is 75,000 km in length, formed when tectonic plates move apart and new crust forms. Plateaux are geologically not as well defined or as extensive as ridges but comprise relatively less steep and shallower features separated from continental shelves by deep channels. They usually are located nearer to land and are considered richer in terms of harvestable resources than oceanic ridges. Trenches are long, narrow depressions of the seafloor and are often very deep and asymmetrical, with relatively steep sides. They have flat floors with accumulated fine sediments. Trenches are formed when oceanic plates collide with continental plates; the heavier oceanic plates are subducted, creating a trench.

2. RELEVANCE

Deep-sea features must be assessed, owing to the increasing levels of human activity and potential threats to these ecologically sensitive areas. Understanding the significance and vulnerability of the features helps to develop conservation and management strategies to preserve marine biodiversity.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Bearing in mind that 66 per cent of the seabed from 200 to 1,000 m in depth, 72 per cent from 1,000 to 3,000 m in depth and 93 per cent of the seabed deeper than 3,000 m remains unmapped, and a large area of the seafloor has never been surveyed for biology, the deep ocean remains a black box in global model simulations. For ridges, plateaux and trenches, major data gaps include basic aspects of biodiversity, ecological and environmental data, critical to addressing ecosystem responses to disturbance. Access to the deep ocean is constrained to a few developed countries, mainly for financial and technical reasons. Collaborative and interdisciplinary research networks have been suggested as an effective way to bridge that gap, given that a vast portion of the deep ocean is within the exclusive economic zones of developing countries and the high seas.

P. Hydrothermal vents and cold seeps

The analysis in this section is based on chapter 7P of *The Second World Ocean Assessment*.

1. INTRODUCTION

Hydrothermal vents are features on the seabed from which heated seawater is discharged. Cold seeps are submarine springs where hydrocarbon-rich fluids emanate from the seabed, originating from buried organic matter, fossil fuel reservoirs or methane hydrates.

2. RELEVANCE

Hydrothermal vents and cold seeps are important to local biodiversity and biogeography and to the flux of greenhouse gases to the atmosphere, with long-distance effects on both the seabed and the water column. They serve as ecological models for understanding adaptation and resilience in extreme conditions and offer potential for biotechnological and biomedical innovation. In addition, they are important in mineral resources exploration.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Hydrothermal vents and cold seeps are generally features of the deep sea. Consequently, data gaps identified with other deep-sea features, namely basic aspects of biodiversity, ecological and environmental data, critical to addressing ecosystem responses to disturbance, are applicable in connection with hydrothermal vents and cold seeps.

IV. State of human society in relation to the ocean

The analysis in this section is based on chapter 8 of *The Second World Ocean Assessment*.

A. Introduction

The Second World Ocean Assessment includes an analysis of coastal communities and various maritime industries, including the harvesting of food, shipping, seabed mining, offshore hydrocarbon exploration and exploitation, tourism and recreation, use of marine genetic resources, marine renewable energy, production of fresh water by desalinization, and salt production. In addition, it contains an examination of the relationship between human health and the ocean through the lens of the health risks and benefits associated with living in proximity to the sea, including the exposure to contaminated seawater and problems caused by food from the sea.

B. Relevance

About 40 per cent of the global population lives within 100 km of the coast, with coastal communities playing a vital role in supporting all components of the ocean economy, a range of social and cultural values and coastal and marine management and governance. The various economic activities are steadily growing in scale. Shipping is fundamental to the global economy by carrying about 90 per cent by volume of international trade. Coastal tourism represents a substantial proportion of overall economic activity for many countries, in particular small island developing States and archipelagic States.

The benefits to human health from living near the sea include enhanced air quality, exercise opportunities, novel marine-derived pharmaceuticals and ready access to healthy seafood. Risks are posed by tsunamis, storms and tropical cyclones, sea level rise, contaminated food from the sea, chemical contaminants, harmful algal blooms and pathogens, and novel pollutants, such as antibiotics, hormones, nanomaterials and microplastics. Increased knowledge of the links between the ocean and human health will help to improve interventions to protect human health from threats and to increase the health benefits derived by humans from the sea.

C. Current data-collection coverage status

1. COASTAL COMMUNITIES AND MARITIME INDUSTRIES

(a) Coastal communities (geodemographics)

Regular monitoring and assessment of changes in the size of coastal populations have largely occurred at the national or regional level. Little has been published about the total global coastal population since the early 2000s, with studies concentrating mainly on low-elevation coastal zones, owing to their significance in the context of sea level rise. Better information on the state of coastal communities, the threats they face and their economic and social situation is needed, in particular for communities of indigenous peoples, given the crucial roles that they play in maritime industries, in social and cultural aspects and in ocean conservation.

(b) Capture fisheries, shellfish harvesting and aquaculture

The *World Ocean Assessment* includes values of total production and information on the fishing fleet and levels of employment in the industry, including by gender. There have been no recent surveys of death and injuries in the fishing industry, but surveys have previously showed significantly higher levels of such incidents compared with other industries.

(c) Shipping

The shipping sector seems comparatively well-documented with data. With respect to cargo traffic, the *World Ocean Assessment* includes information on the extent of international seaborne trade by commodity type, container shipping routes and lines, fleets and capacities, registries, ownership and control of shipping, and the construction and demolition of ships. Regarding passenger traffic, the *Assessment* is focused mainly on the pattern and level of cruise ship activities, including the global distribution of cruising, number and size of cruise ships, and number and supply countries of passengers. The reported numbers and supply countries for seafarers were based on estimates from 2015 with another survey planned for 2020. In the context of piracy, the total number of attempted and actual cases of piracy and armed robbery against ships by area are reported. Better information is needed on social considerations, such as the rates of injury and death of seafarers and other aspects of their welfare.

(d) Seabed mining

No overview of the economics of seabed mining is available, and there have been no surveys of employment, the occurrence of death and injury to workers or pay across the field.

(e) Offshore hydrocarbons

The Second World Ocean Assessment provides the share of offshore hydrocarbon production as a percentage of global production and information on the main offshore producers and the estimated annual global investment capital expenditure. In addition, it is stated in the *Assessment* that the survey of social aspects of the offshore hydrocarbon industry that was presented in *The First Global Integrated Marine Assessment* remains accurate, with employment numbers fluctuating significantly with changing crude oil prices.

(f) Tourism and recreation

The Second World Ocean Assessment includes data on inbound international tourism by global region and related tourism expenditure. Only limited information is available, however, on the scale of coastal and marine tourism and their growth, as compared with tourism generally, or the importance of domestic coastal tourism. Furthermore, there is a lack of global information on the social and economic aspects of coastal and marine tourism, in particular the extent of the benefits for host countries, and on the status of employment in those industries. The *Assessment* provides limited data on the extent of certain coastal tourist activities, such as scuba diving, whale watching and recreational boating.

(g) Marine genetic resources

To provide an idea of the scale of activity in the sector, which is concentrated in a comparatively small number of countries, the Assessment provides the numbers of clinical trials, regulatory approvals and marketed cosmeceutical ingredients.

(h) Marine renewable energy

The *Assessment* provides an estimate of the total employment levels in the offshore wind energy sector, with an estimate by gender provided only for the onshore and offshore wind energy sector as a whole.

(i) Desalinization

The *Assessment* provides an overview of installed capacity for desalinization at the global level and for the main regions, including disaggregation by processing type. Global statistics for employment in desalinization operations are not available, but an estimate is included in the *Assessment*. Further investigations may be needed on the relationships among discharge designs and impacts on the marine environment.

(j) Salt production

Salt production from the evaporation of seawater is still a significant source of salt around the world. Comprehensive statistics at the global level, however, remain unavailable, although reports are available for some regions. The size of the workforce involved in sea salt production is unknown.

2. HUMAN HEALTH AS AFFECTED BY THE OCEAN

(a) General aspects of the relationship between human health and the ocean

Since the assessment and management of impacts on human health resulting from pressures on the ocean have largely been undertaken separately with little or no collaborative interaction, the need for an interdisciplinary approach and new multinational, interdisciplinary projects in that regard are highlighted in the Assessment.

(b) Health of coastal communities

Studies comparing the health of coastal and inland communities have largely been confined to developed countries.

(c) Effects of exposure to contaminated seawater

Studies in many places have quantified the scale of the risk to human health from contact with seawater containing pathogens. The global impact of poor water quality was examined in a study by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection and the World Health Organization, on the basis of estimates of the number of tourists who swim and of the relative risks at various levels of contamination. More needs to be done to determine the scale and location of illness from swimming in contaminated water. To improve public health, the monitoring of bathing-water quality against developed standards will need to be accompanied by standardized ways of publicizing the results.

(d) Problems for human health posed by food from the sea

Shellfish are the major vector of illnesses caused by pathogens discharged to the sea. Although surveys confirm shellfish-borne viral outbreaks, there is no global database on the scale and location of outbreaks of illness of that kind. With respect to toxic algal blooms, effective monitoring and management programmes are in place in some at-risk regions, with a view to preventing such toxins from entering commercial seafood. Gaps remain related to the extent of contamination of fish and shellfish.

V. Pressures on the marine environment

A. Natural hazards and extreme climate events

The analysis in this section is based on chapter 9 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment includes an analysis of three types of ocean-related extreme climate events, namely marine heatwaves, tropical cyclones and extreme El Niño/ Southern Oscillation events, and provides information on the impact of sea level rise.

2. RELEVANCE

Marine heatwaves, tropical cyclones and extreme El Niño/Southern Oscillation events, and the severity of their impact on nature and human societies, are projected to increase in the future, requiring climate change mitigation efforts to reduce such increases. In addition, coastal cities are more and more susceptible to erosion and flooding, owing to sea level rise, increased storminess and coastal urbanization, which amplifies the need for substantial investment in hard engineered coastal defence measures and nature-based solutions, such as the restoration of natural barriers.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

(a) Marine heatwaves

Satellite observations have shown that marine heatwaves doubled in frequency from 1982 to 2016 and have increased in duration, spatial extent and intensity, largely as a result of increases in mean ocean temperature due to human activity-induced climate change. Early warning systems capable of forecasting marine heatwaves can contribute to reducing vulnerabilities in fishing, tourism and conservation, but are yet unproven on a large scale.

(b) Tropical cyclones

While changes in the frequency and spatial distribution of tropical cyclones are hard to detect in observational records, studies of individual cyclones have shown an influence of anthropogenic climate change on their intensity, in particular associated rainfall, winds and extreme sea level events, and a potential influence on their spatial occurrence, with an observed poleward migration of maximum tropical cyclone intensity in the western North Pacific.

(c) Extreme El Niño/Southern Oscillation events

The El Niño/Southern Oscillation is a coupled atmosphere-ocean phenomenon in the tropical eastern Pacific. It occurs on timescales that range from two to seven years had has wide-ranging climatic effects in many parts of the world, owing to global teleconnections. It is often measured by the surface pressure anomaly difference between Tahiti, French Polynesia, and Darwin, Australia, or the sea surface temperatures in the central and eastern equatorial Pacific. Sustained long-term monitoring and existing forecasting systems may be employed in risk management and adaptation associated with human health, agriculture, fisheries, coral reefs, aquaculture, wildfire, drought and flood management.

(d) Effects of sea level rise

Coastal, archipelagic and small island cities, in particular in low-lying areas, are becoming increasingly susceptible to erosion and sea level rise. As a result, it is likely that many hard engineered structures built to protect the land from the sea will need to be adapted, upgraded or combined with nature-based solutions to keep pace with rising sea levels, which could prove challenging for developing countries.

B. Ocean physical and chemical properties

The analysis in this section is based on chapter 9 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The accelerated increase of anthropogenic carbon dioxide in the atmosphere leads to an increase in the acidification and deoxygenation of the ocean. Such change, combined with changes in ocean temperature and salinity induced by climate change and human activities, are having an impact on marine ecosystems by altering the distribution of marine species, decreasing the ecological value of coastal ecosystems and changing marine primary production.

2. RELEVANCE

Ocean acidification may affect all marine life, for example, through changes in gene expression, physiology, reproduction and behaviour.[1] Ocean acidification affects ecosystem properties, functions and services. It reduces reef resilience on a global scale and exacerbates reef destruction. Some groups of organisms do well in acidified conditions, but many taxa do not.[2] Damage from ocean acidification results in less coastal protection and less habitat for biodiversity and fisheries.[3]

Oxygen is fundamental to life in the oceans: it exerts strong control over biological and biogeochemical processes in the open ocean and coastal waters. The threshold of oxygen concentration or saturation at which life processes diminish varies considerably among species, processes and habitats and is affected by temperature.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Advances in ocean observation systems are required in order to attribute ecosystem impacts to changing ocean chemistry. Global initiatives in ocean research, such as Biogeochemical Argo, the Global Ocean Acidification Observing Network and the Global Ocean Oxygen Network, of the Intergovernmental Oceanographic Commission, are reducing barriers and building capacity through collaboration and partnerships, mentoring and training, and support for the creation of regional hubs. Observation and research efforts on ocean acidification and deoxygenation are concentrated in a small number of countries, leaving significant knowledge and capacity gaps, in particular in the southern hemisphere, small island developing States and least developed countries. Higher capacity to collect complex data and deliver better observations across the globe is required, given that it will improve the predictive power of experiments and ecosystem models replicating real-world scenarios across the world.

1 Ulf Riebsell and Jean-Pierre Gattuso, "Lessons learned from ocean acidification research", *Nature Climate Change*, vol. 5, No. 1 (January 2015), p. 12; and Intergovernmental Panel on Climate Change, *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (2019).

2 Sylvain Agostini and others, "Ocean acidification drives community shifts towards simplified non-calcified habitats in a subtropical temperate transition zone", Scientific Reports, vol. 8 (July 2018).

3 Jason M. Hall-Spencer and Ben P. Harvey, "Ocean acidification impacts on coastal ecosystem services due to habitat degradation", *Emerging Topics in Life Sciences*, vol. 3, No. 2 (May 2019).

C. Nutrient inputs to the marine environment

The analysis in this section is based on chapter 10 of *The Second World Ocean Assessment*.

1. INTRODUCTION

Inputs of nitrogen and phosphorus into coastal ecosystems through river discharges and atmospheric depositions rapidly increased during the twentieth century, primarily as a result of anthropogenic inputs derived from the use of synthetic fertilizers, burning of fossil fuel, cultivation of legumes, production of manure from livestock and municipal waste.

2. RELEVANCE

Excessive inputs of nitrogen and phosphorus led to a global increase in the extent of hypoxia zones, sometimes called dead zones, ocean acidification and toxic algae events, posing a serious threat to the health of coastal ecosystems and their capacity to provide valuable services to society. Toxic algae events lead to the production of toxins, which can cause mass mortalities of fishes and shellfish and harm to the health of people who consume contaminated fish and shellfish or are exposed to the toxins through direct contact.[4] Climate-driven acceleration of the global water cycle, including rises in the magnitude and frequency of major rainfall events, will increase nutrient inputs into coastal waters.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Many large marine ecosystems are hotspots of anthropogenic nutrient-loading in both developed and developing countries. A global watershed model has been developed to provide regional and global perspectives on changing nutrient inputs into coastal systems that connects human activities and natural processes in watersheds with nutrient inputs into coastal systems globally.[5] The lack of data on coastal ecosystems in the southern hemisphere is a critical contributing factor to the gaps in the current understanding of the impacts of anthropogenic nutrient inputs into coastal oceans.

D. Liquid and atmospheric inputs to the marine environment from land, including through groundwater, ships and offshore installations

The analysis in this section is based on chapter 11 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment includes an analysis of the situation concerning a number of hazardous substances in the ocean from water and airborne inputs to the marine environment

4 Patricia M. Gilbert and others, “The global, complex phenomena of harmful algal blooms” *Oceanography*, vol. 18, No. 2 (June 2005).

5 S.P. Seitzinger and others, “Sources and delivery of carbon, nitrogen, and phosphorus to the coastal zone: an overview of Global Nutrient Export from Watersheds (NEWS) models and their application”, *Global Biogeochemical Cycles*, vol. 19, No. 4 (December 2005); and Rosalynn Y. Lee, Sybil Seitzinger and Emilio Mayorga, “Land-based nutrient loading to LMEs: a global watershed perspective on magnitudes and sources”, *Environmental Development*, vol. 17 (January 2016).

from land, including groundwater, ships and offshore installations. The hazardous substances analysed are: persistent organic pollutants, metals, radioactive substances, pharmaceuticals and personal care products, hydrocarbons, rare earth elements and airborne inputs of nitrogen and sulfur oxides.

2. RELEVANCE

Hazardous substances in the ocean have a direct negative impact on human health and indirectly affect human health when marine plants and animals that contain hazardous substances are used as food sources. In addition, they affect the marine environment itself, such as through ocean acidification or eutrophication, potentially making it inimical to ocean life. A greater understanding of the cumulative impacts of multiple hazardous substances on marine biota is needed.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Clear comparisons between the environmental quality of various ocean areas remains a problem because of the use of different measuring techniques and very different ranges of the varieties of chemicals being observed.

In addition, obtaining information on the atmospheric deposition of various pollutants is dependent on the modelling approaches used to increase the spatial coverage. To be able to model the deposition, high-quality data on emissions and deposition is strongly needed. The availability of such data is limited for a large part of the ocean.

E. Inputs and distribution of solid waste, other than dredged material

The analysis in this section is based on chapter 12 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment provides an analysis of the situation concerning activities resulting in marine litter, including plastics, abandoned fishing gear, microparticles and nanoparticles, and estimates of its sources from land, ships and offshore installations; and dumping at sea, including garbage from ships and sewage sludge.

2. RELEVANCE

Marine litter is most apparent on shorelines, where it accumulates as a result of water currents, wave and wind action and river outflows. The accumulation of plastics, predominantly, occurs, however, on the ocean surface in ocean gyres, in the ocean column and seafloor and within marine life, to which it can cause direct harm and, when it is consumed, harm higher trophic level species, including humans. In addition, marine litter affects other uses of the marine environment, including navigation, tourism, aquaculture and fisheries. The deliberate disposal of waste or other materials in the sea affects marine ecosystems and creates environmental challenges.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

The adoption of the United Nations Convention on the Law of the Sea and the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and its 1996 Protocol led to the introduction of regulations for solid waste disposal at sea by coastal States and significant progress in this domain. Substantial underreporting and a lack of published data, however, makes it difficult to track implementation and understand the current extent of the challenge that exists. Some of the contributing factors leading to such knowledge gaps are: a lack of standardization of methods for data collection and analysis and of counts or levels of marine litter between locations, a lack of adequate national or regional monitoring of the quantities and impact of marine litter and a lack of standardized methods for the quantification of microplastics in the marine environment.

F. Changes in erosion and sedimentation

The analysis in this section is based on chapter 13 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment provides information on the patterns of erosion and sedimentation through the dynamics that have been observed historically of the shoreline and sediment.

2. RELEVANCE

Coastal erosion and changes in sedimentation pose severe risks to coastal infrastructure, property, economic activities and ecological systems. Monitoring the coastal trends and changes that accelerate erosion, sedimentation and geomorphological change in coastal ecological systems would improve the ability to model and forecast their dynamics and identify potentially severe impacts.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Increased availability of satellite images and advanced image processing analysis techniques and computing resources have improved the capacity for the global assessment of the changes in coastal erosion and sedimentation. In many regions, however, in particular in developing States, the available data remain insufficient for local and regional decision-making, with many data sets requiring substantial further interpretation and better worldwide spatial resolution.

G. Coastal and marine infrastructure

The analysis in this section is based on chapter 14 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment includes information on the changes in coastal and marine infrastructure, their effect on the coastal community and the potential damage to habitats and ecological systems, including their extent, structures and functions. The changes include coastal offshore land reclamation, coastal development structures, ports, harbours, power cables and submarine communications cables.

2. RELEVANCE

Understanding the correlation between the changes in coastal and marine infrastructure and their potential impacts on the marine environment could improve marine spatial planning and functional analysis and the use of blue infrastructure, resulting in fewer negative effects.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

In general, at the global level, not enough is known about the extent of coastal and marine infrastructure changes and their ecological and socioeconomic impacts. The problems are especially serious for developing countries, mainly owing to the lack of investment in coastal and marine scientific research, including data collection.

H. Capture fisheries and harvesting of wild marine invertebrates

The analysis in this section is based on chapter 15 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment contains an analysis of the status of capture fisheries and harvesting of wild marine invertebrates, including by-catch, post-harvest fish losses, marine protein and oils in agriculture and aquaculture, and illegal, unreported and unregulated fishing.

2. RELEVANCE

Capture fisheries remain a crucial source of nutrition and employment, with 4.3 billion people dependent upon fisheries for protein and 120 million people involved in capture fisheries, more than 90 per cent of whom are estimated to be involved in small-scale fisheries.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Several knowledge gaps and a lack of related data are identified in *The Second World Ocean Assessment*: an understanding of the impact of climate change on capture fisheries, of the ecological significance of unexploited stocks in deep-sea environments and of the ability of recovered ecosystems to assume their former roles.

I. Aquaculture

The analysis in this section is based on chapter 16 of *The Second World Ocean Assessment*.

1. INTRODUCTION

Aquaculture broadly concerns the cultivation of aquatic organisms in controlled aquatic environments for any commercial, recreational or public purpose. An analysis of the status of the aquaculture sector is set out in *The Second World Ocean Assessment*.

2. RELEVANCE

Aquaculture contributes to human nutrition and improves it for the rural poor, in particular mothers and young children. It supports livelihoods across the world. Aquaculture is growing at a faster rate than other major food production sectors and it produces food that is high in protein, contains essential micronutrients and, sometimes, contains essential fatty acids that cannot be substituted by other foods.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

The rapid growth of intensive aquaculture is a relatively new phenomenon. As a result, there are significant knowledge gaps and a lack of related data for the proper assessment of its consequences for the environment, human health and social issues, and for a thorough understanding of the impact of climate change on aquaculture and the correct management of seeds, feeds and health.

J. Seaweed harvesting and use

The analysis in this section is based on chapter 17 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment includes an analysis of the current state of seaweed farming and harvesting through several topics, including the uses by humans and economic system services.

2. RELEVANCE

Seaweed is used for human consumption, as food and prebiotics in aquaculture, in food processing, as an animal feed additive, as fertilizers, in water purification and in industrial, cosmetic and medical applications. Collecting data and information on the socioeconomic and environmental impact of seaweed farming and wild harvesting would provide valuable information on their benefits and environmental impact, in particular with regard to climate change mitigation and adaptation.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Seaweed production has been steadily rising to meet the market demand. Such growth has been followed by emerging knowledge gaps and an absence of data on the biology of many seaweed species, including species that are already being farmed and harvested, and the effect on climate change mitigation and adaptation. Addressing those gaps would help to create appropriate economic and financial models, safeguarding the future of the global seaweed aquaculture industry.

K. Seabed mining

The analysis in this section is based on chapter 18 of *The Second World Ocean Assessment*.

1. INTRODUCTION

In *The Second World Ocean Assessment* seabed mining is classified into marine aggregate mining (placer diamonds, placer tin, irons and deposits and phosphorite deposits) and deepwater seabed mining (polymetallic nodules, sea floor massive sulfides, or polymetallic sulfides, and cobalt-rich ferromanganese crusts). In addition, the need for data to improve the understanding of the environmental, social and economic aspects of seabed mining sector is highlighted in the Assessment.

2. RELEVANCE

Marine aggregate mining is a major activity that has huge negative impacts on coastal zones, in particular with regard to coastal vulnerability and resilience to flooding, storm surges, tsunamis and rising sea levels. As a result, there is a growing interest in extracting offshore aggregate.

Although there are currently no commercially developed deep-sea mining operations, the legal framework and the technology to enable exploitation activities are steadily progressing, as a result of growing interest.

Various mineral resources are located in multiple geological and oceanographic settings that host a range of communities and habitat types. Understanding the potential effects of seabed mining on those habitats will contribute to avoiding, reducing and mitigating negative impacts.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

As the interest in seabed mining rises and the technologies to make seabed mining possible steadily develop, the focus shifts to understanding the impact on deep-sea ecosystems and deep-sea species. As a result, it has become evident that the collection of baseline data must be expanded, in particular in respect of the characterization of ecosystems and their components, and the natural variations of environmental baselines, including in the shallow-water continental shelf and the deep sea. Baseline ecological information is needed for predicting the ways in which biodiversity, species connectivity and ecosystem functions and services will respond to change.

L. Offshore hydrocarbon exploration, production and decommissioning

The analysis in this section is based on chapter 19 of *The Second World Ocean Assessment*.

1. INTRODUCTION

Offshore hydrocarbon exploration and production are highly capital-intensive activities and employ workers at above-average wage levels. Exploration is maturing in many regions. As major hydrocarbon reservoirs deplete beyond recovery, the industry expects to spend around $100 billion at the global level over the next decade on decommissioning activities.[6] That trend has the potential to create significant employment opportunities, some of which can offset the reduction in jobs in exploration and production.

2. RELEVANCE

The offshore oil and gas sectors have continued to expand globally, in particular in deep and ultradeep waters. Understanding the correlation among exploration and production trends, social and economic aspects, emerging technologies and potential future trends with possible environmental impacts is vital to minimizing the effect on the environment.

Hydrocarbon resources, accumulated under impermeable rock formations, are identified by analysing geological and geophysical data that are collected during surveys. Geological and geophysical data are used to provide an assessment of marine mineral, archaeological and benthic resources. Data compiled during the long-term monitoring of oil and gas exploration and development are used as a baseline to determine trends and establish mitigation strategies.

Studies have shown that offshore platforms contribute hard engineering structures to the marine environment and, in the process, provide food sources and complex physical habitats for a variety of organisms. In an attempt to minimize the detrimental effect on those habitats, stakeholders are evaluating the alternatives to the physical removal of offshore installations.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

The short-term impacts of oil and gas exploration, development and decommissioning on the marine environment have been studied extensively. Understanding the long-term effects at the global level, however, requires the development of monitoring programmes for the systematic measurement of important environmental, social and economic indicators over time, which will help with the design and implementation of effective policies and mitigation measures to ensure that resources are developed in an environmentally responsible manner.

M. Anthropogenic noise

The analysis in this section is based on chapter 20 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The past few decades have been characterized by an increased awareness of the importance of sound to marine life and a greater understanding of the potential impact of anthropogenic

6 The UK Oil and Gas Industry Association Limited, *Decommissioning Insight* 2018 (2018).

noise on such life. *The Second World Ocean Assessment* includes a description of the sources and primary drivers of anthropogenic noise and its regional variations, including areas where it is expected to increase, its impacts and the current state of knowledge of it, including gaps in knowledge and capacity-building.

2. RELEVANCE

Population growth, migration to coastal areas, increased industrialization and tourism, and other developments are expected to result in an increase in activities that contribute to anthropogenic noise, unless they are accompanied by mitigation efforts, which are being initiated. The adequate protection of the marine environment is not possible without a consensus on a global approach to filling knowledge gaps related to the impact of anthropogenic noise. States have been encouraged to study anthropogenic noise in order to develop guidelines and conduct mitigation efforts.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

As part of regional and national initiatives, States are developing ocean noise-targeted projects, including noise registers or databases with specifications on impulsive noise activity, that are expected to result in an increased ability to map variability in sound levels and efforts to standardize data collection and measurements.

The global recognition of sound as an essential ocean and cross-disciplinary variable and the incorporation of observation systems into new initiatives were expected to contribute to an increase in the monitoring of anthropogenic noise and a better understanding of its contributions to ambient sound and possible changes in soundscapes over time.

Fundamental challenges in evaluating the relative increases and possible impacts of anthropogenic noise in the ocean include a lack of knowledge and related data on baseline ocean ambient noise and of understanding of the impacts of noise on marine ecosystems. Most work to date has been focused on the impact of a single stressor on a particular species. Difficulties of studying the impacts of anthropogenic noise on population levels, in combination with other stressors and on multiple species, was acknowledged in the Assessment. The ability to integrate effects and impacts across different scales and sources must be expanded, in order to allow for a realistic assessment of the impact of anthropogenic noise on marine animals. In the meantime, a precautionary approach is being followed in regulations on the basis of insufficient data. Substantial efforts are needed to standardize monitoring approaches, measurements and archival frameworks or systems for acoustic recording approaches and associated collected data.

N. Renewable energy sources

The analysis in this section is based on chapter 21 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment includes an analysis of the advances in knowledge of and capacity for various types of marine renewable energy at the global level, including offshore wind energy, tidal and ocean current energy, wave energy, ocean thermal energy, osmotic power, marine biomass energy and offshore solar and geothermal energy.

2. RELEVANCE

The sharing of data and information is an important driver of cost reduction, which must be addressed in order for marine renewable energy technologies to be commercially viable. Knowledge-generation is also important for fostering the integration of marine renewable energy into national policies. Monitoring advances in knowledge of and capacity for marine renewable energy is relevant to its potential role as a major contributor to the achievement of renewable energy production targets.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Some data are available regarding developments in marine renewable energy, including energy capacity increases, in particular for offshore wind as the leading example of technology in the sector. Although some data are available regarding the environmental effects of offshore wind projects, the environmental impacts of other marine renewable energy devices have not been studied in detail, owing to the scarcity of operating wave energy converters and tidal and ocean current turbines. More data and coordinated studies are needed to gain a full picture of the environmental impacts of various types of marine renewable energy devices.

Data collection will be important for environmental monitoring and mitigation measures. Establishing environmental baselines and monitoring biotic elements are necessary to addressing any adverse impact on biodiversity of marine renewable energy activities. Standards must be defined for analysing environmental monitoring data for marine renewable energy development sites and for identifying the area over which biological effects may occur, in order to inform baseline data collection. The marine renewable energy technologies used and the stressors introduced in the marine environment should be considered when designing monitoring procedures. Predictive models can be a supplementary tool, ideally when combined with localized observations. Oceanographic and meteorological data can be obtained from on-site measurements, outputs from numerical models and remote sensing instruments. Long-term data are required for the preliminary estimation of the available marine renewable energy resource and the oceanographic and meteorological climate characteristics in the area of the installation. In addition, short-term and medium-term forecasting of oceanographic and meteorological conditions is important for operational planning activities. During operations, reliable short-term forecasts of expected power production are required for large-scale power integration.

O. Invasive species

The analysis in this section is based on chapter 22 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The Second World Ocean Assessment includes an analysis of invasions by marine non-indigenous species, in particular with a view to documenting their baseline status, changes and consequences for human communities, economies and well-being, with a focus on several regional aspects.

2. RELEVANCE

Most non-indigenous species have triggered negative ecological, socioeconomic or human health consequences. Trade and climate change are likely to increase further biological invasions and associated biosecurity and biodiversity risks.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Although data have been collected on some species, areas or effects at particular times, no surveys on a larger scale, covering a broad range of species and impacts, have yet been performed. Similarly, the means through which invasions occur, such as through ballast water, biofouling, canals, aquaculture, trade or debris, have not been sufficiently understood and comprehensive monitoring to detect invasion does not occur. Better data are needed to understand the species, areas, time frames and means associated with invasions. Such data could support good ocean governance and help to address risks associated with invasive species, including with a view to ending poverty and hunger and improving health, access to water and economic growth.

To appreciate the problem better at the global level, by improving the understanding of the locations of species and the ways that they arrived there, accessible and searchable databases, including detailed, validated and georeferenced inventories, are needed. An improved geospatial and temporal understanding of the means of invasion is essential to informing policy and management decisions within and beyond areas of national jurisdiction.

P. Exploration for and use of marine genetic resources

The analysis in this section is based on chapter 23 of *The Second World Ocean Assessment*.

1. INTRODUCTION

The exploration for and use of marine genetic resources refers to the discovery, analysis and application of genetic materials derived from marine organisms. Such resources encompass a wide range of organisms, including microorganisms, algae, invertebrates and fish, and hold significant potential for various industries, including pharmaceuticals, cosmetics and biotechnology. The exploration and use of marine genetic resources have gained considerable attention in recent years, owing to their biological and chemical diversity and their potential economic and environmental benefits.

2. RELEVANCE

Marine organisms are known to produce unique and bioactive compounds that have the potential to be developed into new drugs and therapies. Many marine-derived drugs have already been approved for medical use, in particular in the field of anticancer chemotherapy. In addition, marine organisms provide a rich source of bioactive compounds for the development of cosmetic products that have added therapeutic benefits. Furthermore, marine genetic resources have implications for biotechnology. Advances in that field, such as genetic engineering and synthetic biology, have opened up new avenues for harnessing the potential of marine genetic resources. Such resources can be used for the production of valuable enzymes, biomaterials and biofuels, among other applications. The exploration and use of marine genetic resources can contribute to the development of sustainable and environmentally friendly technologies.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

The collection and documentation of data related to marine genetic resources are crucial for understanding diversity and potential applications of the resources. Efforts have been made to enhance data-collection coverage through various initiatives and projects. Despite those efforts, gaps remain in data-collection coverage, in particular in underexplored regions, such as the deep sea and polar regions. To ensure comprehensive coverage of marine genetic resources, ongoing efforts are needed to expand sampling in those underrepresented areas. Collaboration among researchers, institutions and governments is crucial for collecting and sharing data and knowledge.

Q. Marine hydrates

The analysis in this section is based on chapter 24 of *The Second World Ocean Assessment*.

1. INTRODUCTION

Marine hydrates are crystalline compounds which exist primarily on continental slopes in areas with large quantities of methane gas, where the temperature is sufficiently low and the pressure is sufficiently high for their formation and maintenance. Methane hydrate is the most common marine hydrate. *The Second World Ocean Assessment* includes a fuller assessment of the abundance of marine hydrates, their potential as a source of energy and the associated risks for the atmosphere and in seabed stability.

2. RELEVANCE

As a source of natural gas, marine hydrates have the potential to be a future energy source where they exist in large deposits. Methane, however, is a greenhouse gas that is estimated to be 25 times more consequential for the climate than carbon dioxide. Some research indicates that there might be a connection between global warming and methane release into the atmosphere, given that the stability of gas hydrates depends on temperature and pressure.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Research programmes on the use of marine hydrates as a source of natural gas have been established in some States, and exploration activities have identified promising deposits in some regions. Knowledge gaps remain, however, in relation to the global distribution and size of methane hydrate deposits. Many assessments of those deposits are largely based on extrapolation rather than direct observation and on estimates of the volume of the methane hydrate stability zone, regardless of evidence of the presence of gas. In addition, there are gaps in understanding marine hydrates, such as their behaviour in changing circumstances, in particular changes in ocean temperature, their potential dissociation and the behaviour of any methane that is released, their impact on climate and slope stability, and their contribution to ocean acidification. The knowledge gaps may be significant in relation to the release of oceanic methane into the atmosphere and its potential function as a greenhouse gas.

VI. Management approaches to the marine environment

A. Marine spatial planning

The analysis in this section is based on chapter 26 of *The Second World Ocean Assessment*.

1. INTRODUCTION

Marine spatial planning is aimed at resolving increasing conflicts related to the growing scale of human activities and their associated impact on the marine environment.

2. RELEVANCE

Defining and analysing existing and future conditions are essential in the process of marine spatial planning. Potential conflicts and compatibilities among existing human activities and between those activities and the protection and preservation of the marine environment can thus be identified.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Marine spatial planning is defined as the public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that are usually specified through a political process. Consequently, the availability of spatial and temporal data and information about the ecological, environmental and oceanographic conditions of the targeted sea area is an essential basis for effective marine spatial planning. As a result, more effective marine spatial planning is generally present where greater coverage of related spatial and temporal data exist.

B. Management approaches

The analysis in this section is based on chapter 27 of *The Second World Ocean Assessment*.

1. INTRODUCTION

Marine ecosystem management, comprising decision-making processes and management tools, is a critical part of safeguarding the health of the ocean and its resources. It is generally agreed that the ecosystem approach provides an effective framing of ocean management. Implementing the ecosystem approach, however, faces challenges, owing to regional disparities in skills, financial capacity and resources.

2. RELEVANCE

Managing marine ecosystems is essential to addressing increasing marine environmental challenges. Notably, marine protected areas have rapidly increased in number and size, largely in response to internationally agreed targets under the Convention on Biological Diversity and the 2030 Agenda. Many other types of area-based management tools have been implemented. Regions with limited capacity, however, struggle to implement the ecosystem approach, leading to decades of degradation in marine and coastal areas, with effective management remaining hindered by inadequate plans and enforcement measures. Climate change has emerged as a significant driver for the prioritization of restoration efforts to protect communities and marine habitats worldwide.

3. CURRENT DATA-COLLECTION COVERAGE STATUS

Data collection for marine management is often set back by a lack of information of appropriate quality and quantity. Although big data methods and innovative data use show promise, understanding ecological causes and effects related to socioeconomic priorities remains limited in many regions. Knowledge-sharing and open access to information across sectors are crucial to improving data availability. Citizen science programmes are gaining importance as a valuable source of monitoring data. Effective marine ecosystem management requires regional disparities to be addressed, data availability to be expanded and the diverse values associated with the marine environment to be understood. Timely action and collaboration are vital to ensuring a sustainable future for the ocean.

ANNEX II: MARINE GEOSPATIAL INFORMATION MANAGEMENT – SUCCESS STORIES AT NATIONAL AND REGIONAL LEVELS

Annex II is available at www.un.org/Depts/los/doalos_publications/publicationstexts/annex2.pdf

ANNEX III: MARINE GEOSPATIAL INFORMATION MANAGEMENT – INTERGOVERNMENTAL ORGANIZATIONS

Annex III is available at www.un.org/Depts/los/doalos_publications/publicationstexts/annex3.pdf.

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